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Devonian Fossils from Chitral and the Pamirs Vol VI, Memoir No 2 (1922), pp 136, pls 16, by F R C Reed Price 4 Rs
Ordovician and Silurian Fossils from Yunnan Vol VI Memoir No 3 (1917), pp 69, pls 8, by F R C Reed Price 2 Rs
Upper Carboniferous Fossils from Chitral and the Pamirs Vol VI Memoir No 4 (1925), pp 134 pls 10 by F R C Reed Price 9 Rs 13 A
Indian Gondwana Plants A Revision Vol VII Memoir No 1 (1920), pp 41, pls 7, by A C Seward and B Sahni Price 1 Re 12 As
The Lamellibranchiata of the Eocene of Burma Vol VII, Memoir No 2 (1923), pp 24, pls 7, by Dr G de P Cotter Price 3 Rs 10 As
Review of the Genus Gisortia Vol VII Memoir No 3 (in the press)
An incomplete skull of Dinotherium with notes on the Indian forms Vol VII, Memoir No 4 (1924), pp 13, pls 3, by R W Palmer Price 1 Re 2 As
Contributions to the Palæontology of Assam Vol VIII Memoir No 1 (1923) pp 73, pls 4, by Erich Spengler Price 5 Rs
The Anthracotheriidæ of the Dera Bugti deposits in Baluchistan Vol VIII, Memoir No 2 (1924), pp 59 pls 7 by C Forster Cooper Price 4 Rs
The Perissodactyla of the Eocene of Burma Vol VIII, Memoir No 3 (1925), pp 28 pls 2, by Dr G E Pilgrim Price 1 Re 0 As
The Fossil Suidæ of India Vol VIII, Memoir No 4 (in the press) by Dr G E Pilgrim
On the Blake Collection of Ammonites from Kachh: Vol IX, Memoir No 1 (1924), pp 29, by L F Spath Price 12 As
Palæozoic and Mesozoic Fossils from Yunnan: Vol. X, Memoir No 1 (in the press), by F. R. C Reed.
Index to the Genera and Species described in the Palæontologia Indica, up to the year 1891. Price 1 rupee.

7

RECORDS OF THE GEOLOGICAL SURVEY OF INDIA.

Vol. I, 1868

Part 1 (out of print).—Annual report for 1867. Coal-seams of Tawa valley. Coal in Garrow Hills. Copper in Bundelkund. Meteorites.

Part 2 (out of print).—Coal-seams of neighbourhood of Chanda. Coal near Nagpur. Geological notes on Surat Collectorate. Cephalopodous fauna of South Indian cretaceous deposits. Lead in Raipur district. Coal in Eastern Hemisphere. Meteorites.

Part 3 (out of print).—Gastropodous fauna of South Indian cretaceous deposits. Notes on route from Poonah to Nagpur *via* Ahmednuggur, Jalna, Loonar, Yeotmahal, Mangali and Hingunghat. Agate-flake in pliocene (?) deposits of Upper Godavery. Boundary of Vindhyan series in Rajputana. Meteorites.

Vol. II, 1869

Part 1 (out of print).—Valley of Poorna river, West Berar. Kuddapah and Kurnool formations. Geological sketch of Shillong plateau. Gold in Singhbhoom, etc. Wells at Hazareebagh. Meteorites.

Part 2 (out of print).—Annual report for 1868. Pangshura tecta and other species of Chelonia from newer tertiary deposits of Nerbudda valley. Metamorphic rocks of Bengal.

Part 3 (out of print).—Geology of Kuch, Western India. Geology and physical geography of Nicobar Islands.

Part 4 (out of print).—Beds containing silicified wood in Eastern Prome, British Burma. Mineralogical statistics of Kumaon division. Coal-field near Chanda. Lead in Raipur district. Meteorites.

Vol. III, 1870

Part 1 (out of print).—Annual report for 1869. Geology of neighbourhood of Madras. Alluvial deposits of Irrawadi, contrasted with those of Ganges.

Part 2 (out of print).—Geology of Gwalior and vicinity. Slates at Chitrol, Kumaon. Lead vein near Chicholi, Raipur district. Wardha river coal-fields, Berar and Central Provinces. Coal at Karba in Bilaspur district.

Part 3 (out of print).—Mohpani coal-field. Lead-ore at Slimanabad, Jabalpur district. Coal east of Chhattisgarh between Bilaspur and Ranchi. Petroleum in Burma. Petroleum locality of Sudkal, near Futtijung, west of Rawalpindi. Argentiferous galena and copper in Manbhum. Assays of iron ores.

Part 4 (out of print).—Geology of Mount Tilla, Punjab. Copper deposits of Dalbhum and Singhbhum: 1.—Copper mines of Singhbhum: 2.—Copper of Dalbhum and Singhbhum. Meteorites.

Vol. IV, 1871

Part 1 (out of print).—Annual report for 1870. Alleged discovery of coal near Gooty, and of indications of coal in Cuddapah district. Mineral statistics of Kumaon division.

Part 2 (out of print).—Axial group in Western Prome. Geological structure of Southern Konkan. Supposed occurrence of native antimony in the Straits Settlements. Deposit in boilers of steam-engines at Raniganj. Plant-bearing sandstones of Godavari valley, on southern extensions of Kamthi group to neighbourhood of Ellore and Rajamandri, and on possible occurrence of coal in same direction.

Part 3 (out of print).—Borings for coal in Godavari valley near Dumaguden and Bhadrachalam. Narbada coal-basin. Geology of Central Provinces. Plant-bearing sandstones of Godavari valley.

Part 4 (out of print).—Ammonite fauna of Kutch. Raniganj (and Hengir Gangpur) Coal-field. Sandstones in neighbourhood of first barrier on Godavari, and in country between Godavari and Ellore.

Vol. V, 1872

Part 1 (out of print).—Annual report for 1871. Relations of rocks near Murree (Mari), Punjab. Mineralogical notes on gneiss of South Mirzapur and adjoining country. Sandstones in neighbourhood of first barrier on Godavari, and in country between Godavari and Ellore.

Part 2 (out of print).—Coasts of Baluchistan and Persia from Karachi to head of Persian Gulf, and some of Gulf Islands. Parts of Kummummet and Hanamconda districts in Nizam's Dominions. Geology of Orissa. New coal-field in south-eastern Hyderabad (Deccan) territory.

Part 3 (out of print)—Maskat and Massandim on east of Arabia. Example of local jointing. Axial group of Western Prome. Geology of Bombay Presidency.
Part 4 (out of print)—Coal in northern region of Satpura basin. Evidence afforded by raised oyster banks on coasts of India, in estimating amount of elevation indicated thereby. Possible field of coal measures in Godavari district, Madras Presidency. Lameta or infra-trappean formation of Central India. Petroleum localities in Pegu. Supposed eozoonal limestone of Yellam Bile.

Vol. VI, 1873.

Part 1.—Annual report for 1872. Geology of North-West Provinces.
Part 2 (out of print).—Bisrampur coal-field. Mineralogical notes on gneiss of south Mirzapur and adjoining country.
Part 3 (out of print). Celt in ossiferous deposits of Narbada valley (Pliocene of Falconer): on age of deposits and on associated shells. Barakars (coal-measures) in Beddadanole field, Godavari district. Geology of parts of Upper Punjab. Coal in India. Salt-springs of Pegu.
Part 4 (out of print). Iron deposits of Chanda (Central Provinces). Barren Islands and Narkondam. Metalliferous resources of British Burma.

Vol. VII, 1874.

Part 1 (out of print). Annual report for 1873. Hill ranges between Indus valley in Ladak and Shah-i-Dula on frontier of Yarkand territory. Iron ores of Kumaon. Raw materials for iron-smelting in Raniganj field. Elastic sandstone, or so-called Itacolumyte. Geological notes on part of Northern Hazaribagh.
Part 2 (out of print). Geological notes on route traversed by Yarkand Embassy from Shah-i-Dula to Yarkand and Kashgar. Jade in Karakas valley, Turkistan. Notes from Eastern Himalaya. Petroleum in Assam. Coal in Garo Hills. Copper in Narbada valley. Potash-salt from East India. Geology of neighbourhood of Mari hill station in Punjab.
Part 3 (out of print). Geological observations made on a visit to Chaderkul, Thian Shan range. Former extension of glaciers within Kangra district. Building and ornamental stones of India. Materials for iron manufacture in Raniganj coal-field. Manganese ore in Wardha coal-field.
Part 4 (out of print). Auriferous rocks of Dhambal hills, Dharwar district. Antiquity of human race in India. Coal recently discovered in the country of Luni Pathans, south-east corner of Afghanistan. Progress of geological investigation in Godavari district, Madras Presidency. Subsidiary materials for artificial fuel.

Vol. VIII, 1875.

Part 1 (out of print). Annual report for 1874. The Altum-Artush considered from geological point of view. Evidences of 'ground-ice' in tropical India, during Talchir period. Trials of Raniganj fire-bricks.
Part 2 (out of print). Gold-fields of south-east Wynaad, Madras Presidency. Geological notes on Khareean hills in Upper Punjab. Water-bearing strata of Surat district. Geology of Scindia's territories.
Part 3 (out of print)—Shahpur coal-field, with notice of coal explorations in Narbada region. Coal recently found near Moflong, Khasia Hills.
Part 4 (out of print). Geology of Nepal. Raigarh and Hingir coal-fields.

Vol. IX, 1876.

Part 1 (out of print).—Annual report for 1875. Geology of Sind.
Part 2 (out of print). Retirement of Dr. Oldham. Age of some fossil floras of India. Cranium of Stegodon Ganesa, with notes on sub-genus and allied forms. Sub-Himalayan series in Jamu (Jammoo) Hills.
Part 3 (out of print). Fossil floras in India. Geological age of certain groups comprised in Gondwana series of India, and on evidence they afford of distinct zoological and botanical terrestrial regions in ancient epochs. Relations of fossiliferous strata at Maleri and Kota, near Sironcha, C. P. Fossil mammalian faunæ of India and Burma.
Part 4 (out of print)—Fossil floras in India. Osteology of Merycopotamus dissimilis. Addenda and Corrigenda to paper on tertiary mammalia. Plesiosaurus in India. Geology of Pir Panjal and neighbouring districts.

Vol. X, 1877.

Part 1 (out of print).—Annual report for 1876. Geological notes on Great Indian Desert between Sind and Rajputana. Cretaceous genus Omphalia near Nameho lake, Tibet, about 75 miles north of Lhassa. Estheria in Gondwana formation. Vertebrata from Indian tertiary and secondary rocks. New Emydine from the upper tertiaries of Northern Punjab. Observations on under-ground temperature.

Part 2 (out of print).—Rocks of the Lower Godavari. 'Atgarh Sandstones' near Cuttack. Fossil floras in India. New or rare mammals from the Siwaliks. Aravali series in North-Eastern Rajputana. Borings for coal in India. Geology of India.

Part 3 (out of print)—Tertiary zone and underlying rocks in North-West Punjab. Fossil floras in India. Erratics in Potwar. Coal explorations in Darjiling district. Limestones in neighbourhood of Barakar. Forms of blowing machine used by smiths of Upper Assam. Analyses of Raniganj coals.

Part 4 (out of print). Geology of Mahanadi basin and its vicinity. Diamonds, gold, and lead ores of Sambalpur district. 'Eryon Comp. Barroveusis,' McCoy, from Sripermatur group near Madras. Fossil floras in India. The Blaini group and 'Central Gneiss' in Simla Himalayas. Tertiaries of North-West Punjab. Genera Chœromeryx and Rhagatherium.

VOL. XI, 1878.

Part 1.—Annual report for 1877. Geology of Upper Godavari basin, between river Wardha and Godavari, near Sironcha. Geology of Kashmir, Kishtwar, and Pangi. Siwalik mammals. Palæontological relations of Gondwana system. 'Erratics in Punjab.'

Part 2 (out of print).- Geology of Sind (second notice). Origin of Kumaun lakes. Trip over Milam Pass, Kumaun. Mud volcanoes of Ramri and Cheduba. Mineral resources of Ramri Cheduba and adjacent islands.

Part 3.- Gold industry in Wynaad. Upper Gondwana series in Trichinopoly and Nellore Kistna districts. Senarmontite from Sarawak.

Part 4.—Geographical distribution of fossil organisms in India. Submerged forest in Bombay Island.

VOL. XII, 1879.

Part 1.- Annual report for 1878. Geology of Kashmir (third notice). Siwalik mammalia. Siwalik birds. Tour through Hangrang and Spiti. Mud eruption in Ramri Island (Arakan). Braunite, with Rhodonite, from Nagpur, Central Provinces. Palæontological notes from Satpura coal basin. Coal importations into India.

Part 2.- Mohpani coal field. Pyrolusite with Psilomelane at Gosalpur, Jabalpur district. Geological reconnaissance from Indus at Kushalgarh to Kurram at Thal on Afghan frontier. Geology of Upper Punjab.

Part 3.—Geological features of northern Madras, Pudukota State, and southern parts of Tanjore and Trichinopoly districts included within limits of sheet 80 of Indian Atlas. Cretaceous fossils from Trichinopoly district, collected in 1877-78. Sphenophyllum and other Equisetaceæ with reference to Indian form Trizygia Speciosa, Royle (Sphenophyllum Trizygia, Ung.). Mysorin and Atacamite from Nellore district. Corundum from Khasi Hills. Joga neighbourhood and old mines on Nerbudda.

Part 4.—'Attock Slates' and their probable geological position. Marginal bone of undescribed tortoise, from Upper Siwaliks, near Nila, in Potwar, Punjab. Geology of North Arcot district. Road section from Murree to Abbottabad.

VOL. XIII, 1880.

Part 1.- Annual report for 1879. Geology of Upper Godavari basin in neighbourhood of Sironcha. Geology of Ladak and neighbouring districts. Teeth of fossil fishes from Ramri Island and Punjab. Fossil genera Noggerathia, Stbg., Noggerathiopsis, Fstm., and Rhiptozamites, Schmalh., in palæozoic and secondary rocks of Europe, Asia and Australia. Fossil plants from Kattywar, Shekh Budin, and Sirgujah. Volcanic foci of eruption in Konkan.

Part 2.—Geological notes. Palæontological notes on lower trias of Himalayas. Artesian wells at Pondicherry, and possibility of finding sources of water-supply at Madras.

Part 3. Kumaun lakes. Celt of palæolithic type in Punjab. Palæontological notes from Karharbari and South Rewa coal fields. Correlation of Gondwana flora with other floras. Artesian wells at Pondicherry. Salt in Rajputana. Gas and mud eruptions on Arakan coast on 12th March 1879 and in June 1843.

Part 4 (out of print). Pleistocene deposits of Northern Punjab, and evidence they afford of extreme climate during portion of that period. Useful minerals of Arvali region. Correlation of Gondwana flora with that of Australian coal-bearing system. Reh or alkali soils and saline well waters. Reh soils of Upper India. Naini Tal landslip, 18th September 1880.

VOL. XIV, 1881.

Part 1. Annual report for 1880. Geology of part of Dardistan, Baltistan, and neighbouring districts. Siwalik carnivora. Siwalik group of Sub-Himalayan region. South Rewah Gondwana basin. Ferruginous beds associated with basaltic rocks of north-eastern Ulster, in relation to Indian laterite. Rajmahal plants. Travelled blocks of the Punjab. Appendix to 'Palæontological notes on lower trias of Himalayas.' Mammalian fossils from Perim Island.

Part 2.—Nahan Siwalik unconformity in North-Western Himalaya. Gondwana vertebrates. Ossiferous beds of Hundes in Tibet. Mining records and mining record office of Great Britain; and Coal and Metalliferous Mines Act of 1872 (England).

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part I] **1926.** **[April.**

GENERAL REPORT FOR 1925. BY E. H. PASCOE, M.A., Sc.D. (Cantab.), D.Sc. (Lond.), F.G.S., F.A.S.B., *Director, Geological Survey of India.*

DISPOSITION LIST.

DURING the period under report the officers of the Department were employed as follows:

Superintendents.

DR. L. L. FERMOR — Returned from the field on the 3rd March 1925. Officiated as Director from 10th March to the 4th November 1925. Placed in charge of the Central Provinces and Central India Party and left for the field on the 19th November 1925.

DR. G. E. PILGRIM — Remained at headquarters and acted as Palæontologist up to the 13th March 1925. Placed in charge of the Punjab Party and left for the field on the 13th March. Returned from the field on the 16th June. Granted combined leave for one year and four months with effect from the 13th July 1925.

MR. G. H. TIPPER	Continued in charge of office throughout the year and also acted as Palæontologist with effect from the 14th March 1925.
DR. G. DE P. COTTER	Returned from leave on the 14th December 1925. Placed in charge of the North-West India Party.
DR. J. COGGIN BROWN	Returned from leave on the 17th October 1925. Placed in charge of the Burma Party and left for Burma on the 8th November 1925.
MR. H. CECIL JONES	Returned from the field on the 14th April 1925. Granted leave on average pay for six months and seven days with effect from the 8th May. Returned from leave on the 16th November. Placed in charge of the Bihar and Orissa Party and left for the field on the 28th November 1925.

Assistant Superintendents.

MR. H. WALKER . .	On combined leave.
MR. K. A. K. HALLOWES	On combined leave.
DR. A. M. HERON	Returned to headquarters from the field on the 7th May 1925. Placed in charge of the Rajputana Party and left for the field on the 9th November 1925.
DR. C. S. FOX	Returned from the field on the 11th May 1925. Granted leave on average pay for four months and thirteen days with effect from the 9th June. Returned from leave and permitted to resume duty at Singareni on the 31st October. Inspected the Singareni coalfield and returned to headquarters on the 4th November. Placed in charge of the Coal-fields Party, and left for the field on the 11th November 1925.

RAO BAHADUR S. SETHU RAMA RAU.	Returned to headquarters from field-work in Burma on the 26th June 1925. Attached to the Coal-fields Party in connection with the re-examination of the Raniganj coalfield. Left for the field on the 13th November 1925.
RAO BAHADUR M. VINAYAK RAO.	Returned to headquarters from field-work in the Madras Presidency on the 12th April 1925. Deputed to investigate the alleged occurrence of coal at Kamasamudram in Mysore State. Left for the field on the 27th May and returned to headquarters on the 21th July. Detailed for the investigation of the manganese and kaolin deposits in the Kanara district of the Bombay Presidency and for the continuance of the geological survey of the districts of Salem and North Arcot in the Madras Presidency. Left for the field on the 2nd November 1925.
MR. H. CROOKSHANK	Returned to headquarters from the field on the 5th May 1925. Attached to the Central Provinces and Central India Party to continue the geological survey of the Chhindwara district. Left for the field on the 22nd October 1925.
MR. E. L. G. CLEGG	Placed in charge of the Burma Party till the arrival of Dr. J. Coggin Brown on the 11th November 1925, and thereafter attached to that Party.
MR. D. N. WADIA	Attached to the North-West India Party. Left for the field on the 6th October 1925.
MR. G. V. HOBSON	At headquarters as Curator of the Geological Museum and Laboratory.

CAPT. F. W. WALKER .	Attached to the Burma Party. Killed on the 20th March 1925.
MR. J. A. DUNN .	Returned to headquarters from his field-work in Bihar and Orissa on the 11th May 1925. Deputed to examine the Khewra salt-mine hill in the Punjab with a view to preparing a geological map of the area and thereafter to investigate the occurrence of aluminous refractory materials in Assam Bihar and Orissa and Central India. Left for the field on the 18th October 1925.
MR. A. L. COULSON	Returned from the field on the 15th June 1925. Attached to the Rajputana Party to continue the geological survey of the Sirohi State. Left for the field on the 27th October 1925.
MR. E. J. BRADSHAW	Returned from field-work in Rajputana on the 13th May 1925. Left headquarters on the 17th July to inspect a fossil tree at Asansol and returned on the following day. Deputed to examine building sites at Bakloh Cantonment and also to report on the deep tube-well boring at Ambala Cantonment. Thereafter attached to the Rajputana Party to continue the geological survey of the Mewar State. Left for the field on the 3rd November 1925.
MR. C. T. BARBER	Returned to headquarters from field-work in Burma on the 25th June 1925. Attached to the Burma Party and left for the field on the 8th September 1925.

MR. E. R. GEE . Deputed to inspect the landslips of the Kalimpong Division, Bengal. Left for the field on the 9th May and returned to headquarters on the 5th July 1925. Attached to the Coal fields Party. Left for the field on the 9th November 1925.

MR. W. D. WEST . Returned from the field on the 1st July 1925. Attached to the Central Provinces and Central India Party. Left for the field on the 16th November 1925.

MR. A. K. BANERJI Returned from the field on the 9th May 1925. Attached to the Coal-fiedls Party. Left for the field on the 7th November 1925.

DR. M. S. KRISHNAN Returned from the field on the 7th May 1925. Attached to the Bihar and Orissa Party; left for the field on the 2nd November 1925.

MR. P. LEICESTER Appointed Assistant Superintendent, Geological Survey of India; joined the Depart ment on the 5th December 1925 Attached to the Burma Party. Left for the field on the 15th December 1925.

DR. S. K. CHATTERJEE Appointed Assistant Superintendent, Geological Survey of India; joined the Department on the 3rd December 1925. Attached to the Rajputana Party. Left for the field on the 21st December.

Chemist.

DR. W. A. K. CHRISTIE At headquarters.

Artist.

MR. K. F. WATKINSON .	At headquarters

Sub-Assistants.

MR. B. B. GUPTA	Returned to headquarters for recess from field-work in Burma on the 4th September 1925. Attached to the Burma Party and left for the field on the 9th November 1925.
MR. D. S. BHATTACHARJI.	Returned to headquarters from field-work in the Central Provinces on the 26th April 1925 Granted leave on average pay from the 12th August to the 5th September 1925. Attached to the Central Provinces and Central India Party. Left for the field on the 18th November 1925.
MR. B. C. GUPTA	Returned to headquarters from field-work in Rajputana on the 3rd May 1925. Attached to the Rajputana Party and left for the field on the 9th November 1925.
MR. H. M. LAHIRI	Attached to the North-West India Party and left for the field on the 18th November 1925.
MR. L. A. NARAYANA IYER.	Returned to headquarters from field-work in Bihar and Orissa on the 23rd April 1925. Attached to the Bihar and Orissa Party and left for the field on the 4th November 1925.
MR P. N. MUKERJEE.	At headquarters.

Assistant Curator.

MR. P. C. ROY . At headquarters.

The cadre of the Department continued to be 6 Superintendents 22 Assistant Superintendents and one Chemist. Of the four vacancies in the grade of Assistant Superintendent including the one caused by the death of Captain F. W. Walker two were filled during the year, leaving at the end of the year two vacancies.

ADMINISTRATIVE CHANGES.

Promotions and appointments.

Dr. L. L. Fermor was appointed to officiate as Director from the 10th March 1925, *vice* Dr. E. H. Pascoe, Director, on leave, and reverted to his substantive appointment on the 5th November 1925. on the return of the latter.

Dr. A. M. Heron continued to officiate as Superintendent up to the 13th December 1925, *vice* Dr. G. de P. Cotter on leave; he was again appointed to officiate as Superintendent from the 14th December 1925, *vice* Dr. G. E. Pilgrim on leave.

Dr. C. S. Fox was appointed to officiate as Superintendent up to the 16th October 1925, *vice* Dr. J. Coggin Brown on leave and from the 17th October to the 13th December 1925, *vice* Dr. G. E. Pilgrim on leave.

Mr. E. L. G. Clegg was appointed to officiate as Superintendent up to the 4th November 1925, *vice* Dr. L. L. Fermor officiating as Director, and from the 5th to the 10th November 1925, *vice* Mr. H. C. Jones on leave.

Mr. G. V. Hobson continued to act as Curator, Geological Museum and Laboratory.

Dr. G. E. Pilgrim acted as Palæontologist till the 13th March 1925 when he was relieved by Mr. G. H. Tipper.

Messrs. E. J. Bradshaw, E. R. Gee and W. D. West have been confirmed in their appointments as Assistant Superintendents.

The following officers joined the Department during the year:—

Mr. P. Leicester, B.A. (Oxon.); appointed Assistant Superintendent with effect from the 5th December 1925.

Dr. S. K. Chatterjee, M.Sc. (Cal.), Ph.D., D.I.C. (Lond.); appointed Assistant Superintendent with effect from the 3rd December 1925.

Leave. Dr. E. H. Pascoe was granted leave on average pay for eight months with effect from the 10th March 1925.

Dr. G. E. Pilgrim was granted combined leave for one year and four months with effect from the 13th July 1925.

Mr. H. C. Jones was granted leave on average pay for six months and seven days with effect from the 8th May 1925.

Dr. C. S. Fox was granted leave on average pay for four months and thirteen days with effect from the 19th June 1925.

Mr. D. Bhattacharji was granted leave on average pay for twenty-five days with effect from the 12th August 1925.

LECTURESHIP.

Mr. D. N. Wadia continued as Lecturer on Geology at the Presidency College, Calcutta, till the 22nd June 1925 when he was relieved by Mr. G. V. Hobson.

POPULAR LECTURES.

Popular lectures were delivered in the Indian Museum during the year, the subjects selected being as follows :—

(1) "Soda in India" by Dr. W. A. K. Christie.
(2) "Roads and Road Metals" by Mr. A. L. Coulson.
(3) "Indian Plateau Basalts" by Mr. H. Crookshank.
(4) "The Origin of the Continents" by Dr. A. M. Heron.
(5) "The Formation of Mountain Ranges" by Dr. A. M. Heron.

LIBRARY.

The additions to the library amounted to 4,577 volumes of which 1,140 were acquired by purchase and 3,437 by presentation and exchange.

PUBLICATIONS.

The following publications were issued during the year under report :—

Records, Vol. LVI, part 3,
Records, Vol. LVII,

Records, Vol. LVIII, parts 1, 2 and 3,
Memoirs, Vol. XXI, part 3 (reprinted),
Memoirs, Vol. XLVIII, part 2,
Memoirs, Vol. I, part 1,
Palæontologia Indica, New Series, Vol. VI, Memoir No. 4,
Palæontologia Indica, New Series, Vol. VIII, Memoirs Nos. and 3.

MUSEUM AND LABORATORY.

Staff.

Mr. G. V. Hobson was Curator of the Geological Museum and Laboratory throughout the year under report. Babu Purna Chandra Roy retained the Assistant Curatorship and Babus Austin Manindranath Ghosh and Dasarathi Gupta fulfilled the duties of Museum Assistants during the period under review.

Chemist.

Dr. W. A. K. Christie, Chemist, remained at headquarters throughout the year and was chiefly engaged in the routine work of the laboratories. He published a paper on zeolites from Bombay, another on the chemical denudation of the Indus and a third on an occurrence of ammonium fluosilicate (cryptohalite) are under preparation.

Determinative work and analyses.

The number of specimens referred to the Curator for examination and report was 789. Assays and analyses were made of 70 specimens. The corresponding figures for 1924 were 574 and 35, respectively. The specimens analysed were largely coals, whose calorific value was determined by the Bomb Calorimeter, but included manganese ores, bauxite, graphite, celadonite, chlorophæite, galena, lead slags, auriferous jamesonite, gypsum and marbles

Donations to Museums, etc.

During the year under review presentations of geological specimens were made to the following :—

(1) The Bengal Technical Institute, Dhakuria, 24-Parganas.
(2) Mr. H. J. Winch, Manager Shivrajpur Syndicate Ld., Panch Mahals, Bombay.
(3) Church Missionary School, Srinagar, Kashmir
(4) The Museum, Jaipur, Rajputana.
(5) Central College, Bangalore.
(6) Uttarpara College, Bengal.

(7) Zurich University; Switzerland.
(8) Oriental Seminary, Calcutta.
(9) Muslim University, Aligarh.
(10) Direccion Estudios Biologicas; Mexico.

In addition to the above general presentations the following specific donations were made :—

(1) Specimens of bauxite to Mr. T. V. Madhava Rao, Imperial College of Science and Technology, London.
(2) Pitchblende, monazite, cyrtolite and samarskite to the Geo-Physical Laboratory, Washington, U.S.A.
(3) Specimen of lazulite-clinozoisite-quartzite with ilmenite and rutile to Professor Tilley, Sedgewick Museum, Cambridge.
(4) Specimen of gyrolite to the Australian Museum, Sydney.

Additions to the General Collections.

The collections received back from the British Empire Exhibition at the end of last year have been returned to the Geological Survey galleries during the year.

Specimens received.

In addition to the large number of rock and mineral specimens collected by members of the Department, the following have been received and included in the collections during the year :—

(1) Briquette of Indian lignite. Presented by Commander Heneage.
(2) Malacon, ilmenorutile, betafite, ampangabeite with columbite, samarskite, euxenite, thortveitite tscheffkinite and bastnæsite; all from Madagascar. Presented by the *Muséum National d'Histoire naturelle*, Paris.
(3) Cinnabar, galena, stibnite, copper ore and native silver; from Mexico. By exchange with the Direccion Estudios Biologicas, Mexico.
(4) A large and interesting collection of mica originally sent to the British Empire Exhibition, now received back and not previously acknowledged. Presented by Messrs. F. F. Chrestien & Co., Ld., Domchanch, Kodarma; Bihar and Orissa.
(5) Materials used in the production of Ferro-tungsten, originally sent to the British Empire Exhibition, now received back and not previously acknowledged. Presented by the High Speed Steel Alloys Co., Ld., Widnes; England.

(6) Chrome briquette from Bangalore. Presented by Messrs. Oakley, Duncan & Co., Ld.

(7) Hollandite from the Shivrajpur mine. Presented by Mr. H. J. Winch, Shivrajpur, Panch Mahals; Bombay.

(8) Green mica from Tibet. Presented by H.E. the Tsarong Shape.

(9) Copper ore, bauxite, barite, steatite, bentonite and zinc blende from Kashmir. Presented by Mr. C. S. Middlemiss.

(10) A core of massive hæmatite from Jamda, Singhbhum district. Presented by Mr. F. G. Percival.

(11) A block of salt with a cavity containing fluid from Shahpur, Punjab. Presented by Mr. J. C. Ferguson.

(12) Pencil crystals of hollandite from Kachi Dhana, Chhindwara district. Presented by Major H. M. Hance.

(13) Cassiterite in pegmatite from the Amherst district, Burma. Presented by Mr. S. H. Harman.

(14) Pieces of sillimanite crucibles. Presented by Professer W. E. S. Turner, Sheffield.

(15) Cryptohalite from Barari. Presented by Mr. R. G. M. Bathgate.

(16) Green marble from Kharwa. Presented by the Rao Sahib of Kharwa.

Meteorite Collection.

During the period under review specimens of the following meteorites have been received from the British Museum and included in our collections :—

Stony Meteorites.

(1) Nakhla, Abu Hommos, Alexandria; Egypt.

(2) Aumale, Alger; Algeria.

Iron Meteorites.

(1) Dalton, Whitfield County, Georgia; United States of America.

(2) Garhi Yasin, Shikarpur *taluk*, Sukker district, Bombay.

(3) Bischtübe, Nikolæv, Turgai; Siberia.

(4) Santa Catharina; Brazil.

The fall of a meteorite was reported to have occurred at Alam Bazar near Calcutta between 8-30 and 9 P.M. on the 14th December 1925, several villagers having testified to seeing an extremely bright flash of light cross from east to west and apparently fall at the above locality. So far the actual spot has not been located and efforts to recover any of the meteoric material have been unsuccessful.

The fossil tree which was transported to Calcutta from Asansol at the end of last year has been re assembled and mounted on the verandah outside the mineral gallery in the Museum. The tree was originally laid out as received and supported on wooden chocks. It was soon apparent that the alternate dryness and damp of the Calcutta climate would result in rapid deterioration; cracks developed between the chocks and the pieces threatened to collapse. A continuous cement pedestal was accordingly built under the tree from end to end. Each piece was fitted into place as accurately as possible and all cracks and joints pointed with Portland cement; the whole was then coated with transparent, waterproof varnish. In this way all strain has been taken off the fragments and it is hoped that the waterproof coating, renewed from time to time, will preserve the tree from the effects of the climate.

Fossil Tree.

During 1925, in the Burma Laboratory 42 specimens have been received and reported upon, of which 18 were quantitatively examined. The corresponding figures for 1924 were 45 and 3 respectively.

Burma Laboratory.

PALÆONTOLOGY.

Dr. G. E. Pilgrim continued to act as Palæontologist until he left for the field in March. Mr. G. H. Tipper then took over the duties of the post and continued to act for the remainder of the year.

During the year under review the following Memoirs have been published in the *Palæontologia Indica* :—

(1) C. Forster Cooper : "Anthracotheriidæ of the Dera Bugti deposits in Baluchistan" Memoir No. 2 of Vol. VIII of the New Series.

(2) G. E. Pilgrim : "Perissodactyla of the Eocene of Burma" Memoir No. 3 of the same volume.

The first portion of the late Mr. E. W. Vredenburg's monograph on the Mollusca of the Post-Eocene deposits of North-Western India has appeared in *Memoirs*, Vol. L, part 1. The second portion is almost ready for issue. The delay is due to the unfortunate disorder in which the collections were left; this has now almost been rectified and most of the missing types have been traced. The following papers of palæontological interest have appeared in the *Records* :—

(1) "A Fresh-water Fish from the Oil-measures of the Dawna hills," by the late Dr. N. Annandale and Dr. Sundar Lal Hora,

(2) "On a fossil Ampullariid from Poonch, Kashmir," by Dr. B. Prashad.

(3) "On a calcareous alga belonging to the Triploporelleæ (Dasycladaceæ) from the Tertiary of India," by John Walton.

(4) "Notes on Cretaceous Fossils from Afghanistan and Khorassan," by the late H. S. Bion.

In the last General Report reference was made to the work of Dr. G. E. Pilgrim on the fossil Suidæ of India. The description of them has been completed and is now almost ready for issue. With twenty plates it will form Memoir No. 4 of Volume VIII of the *Palæontologia Indica*, New Series. The same author also has in hand a description of the Siwalik Carnivora and Antelopes.

Before his lamented death in 1915 the late Mr. Bion had written a description of the fauna of the Agglomeratic Slates of the Kashmir valley. To this Mr. C. S. Middlemiss has now supplied an introduction. This paper, embodying an account of the fauna of one of the most interesting geological horizons in Kashmir, illustrated by eleven plates and a geological map, will be published in the *Palæontologia Indica.*

Dr. L. F. Spath has submitted two fasciculi of his revision of the Jurassic cephalopods of Kachh. In addition to Waagen's original types, he has in his hands a mass of very valuable material collected by Mr. J. H. Smith, and very kindly presented by that gentleman to the Geological Survey of India. The whole of Dr. Spath's work will finally form an authoritative account of a very rich collection.

Dr. Cowper Reed has described the numerous fossils from several horizons, Palæozoic and Mesozoic, collected by Dr. Coggin Brown during his journeys in Yunnan. A provisional list of these has already appeared in the *Records*, volume LV, part 4.

M. Henri Douvillé, to whom the collections from the *Cardita Beaumonti* beds originally sent to M. Cossmann were transferred, states that he has almost completed his descriptions. His account of the fauna of this well-known horizon of North-Western India is awaited with much interest, and will appear in the *Palæontologia Indica.* The same author has also prepared two short papers on some Cretaceous fossils collected by the late Mr. C. L. Griesbach from Herat and by the late Sir Henry H. Hayden from Chitral and Gilgit. These papers will shortly appear in the *Records.*

Major L. M. Davies has prepared two descriptive papers, the first dealing with two new species of the echinoid genus, *Conoclypeus*, and the second with the foraminiferal genus, *Conulites*, and some of its species.

These papers are the result of investigations, extending over a considerable period into the geology of the neighbourhood of Kohat and the Samana range. Foraminifers also form the subject of a paper by Mr. W. L. F. Nuttall, who writes on "the Zonal distribution and description of the larger foraminifera of the Middle and Lower Kirthar Series (Middle Eocene) of parts of Western India," giving stratigraphical details of the deposits, the distribution of the foraminifera, the age of the beds as determined from the larger foraminifera and palæontological descriptions. The paper appears in the present number of the *Records*.

For continued assistance in palæobotanical questions, the Department is indebted to Dr. B. Sahni, Professor of Botany in the University of Lucknow. He has examined the majority of the specimens of botanical interest submitted during the past year and is still engaged on undescribed material collected during recent years. In last year's report mention was made of the discovery of a fossil tree trunk of large size in beds of the Panchet stage near Asansol. This year another similar discovery has to be recorded. This new trunk is only fifty feet long and hence considerably shorter than the previous one; it is, however, of equal girth. The trunk has been brought to Calcutta. The Department is once again greatly indebted to the authorities of the East Indian Railway for their assistance in handling and transporting this large mass. Unfortunately the trunk is in a very broken condition and its restoration will require time and care. So far as can be judged from a cursory examination the tree belongs to the same genus, *Dadoxylon*, as that of the specimens discovered last year.

In general the fossils submitted for examination during the year were not of great interest, although some of them, *e.g.* foraminifera from oil borings, may entail considerable research.

Amongst the more noticeable specimens was a fossil egg discovered by Dr. N. L. Sheldon, Chief Inspector of Explosives in India, and an enthusiastic collector. This interesting object was found in a patch of soft sandy clay in the "Red Bed" of the Yenangyaung Oil-field, due west of the most northerly well of the Burmah Oil Company. Dr. Sheldon recognised the value of his find and was able to extract the whole patch which was brought to Calcutta. Luckily the sandy clay disintegrated readily in water and hence the shell fragments were easily obtained without further damage. The shell was badly broken but taking due regard of the curvature of the fragments, it has been possible to form a very fair reconstruction on a mould of plasticine, about two-thirds of the shell being preserved. The egg is about 2½ inches long by 1½ broad and

is $\frac{1}{2}$-inch thick and is flattened longitudinally. Mr. Tipper, who undertook the examination of the egg, finds that in appearance it is reptilian, but that none of the recent reptilian eggs with which it has been compared shows the flattening to the same extent; this flattening may be due to crushing. Sections of the shell show, according to Mr. Tipper, that the structure is distinctly reptilian in character but not identical with any recent reptilian genus. This comparison was made possible by the Director of the Zoological Survey of India who kindly provided eggs of crocodiles, lizards, tortoises, and various birds. The differences in structure seen may be partly due to secondary changes during fossilisation. A portion of the membrane was seen to be present but this had lost all trace of distinctive structure. From their very nature fossil eggs are necessarily rare objects, and this discovery is one of considerable interest.

Another discovery of interest, made by Major L. M. Davies during his work in the Samana range, consisted of a number of Cretaceous fossils from an horizon hitherto unknown in India. Amongst the specimens are several examples of *Douvilleiceras mammillatum* in a good state of preservation, the identity with the European form being complete. Amongst the other Ammonites are species of the genera *Acanthoceras* and *Hoplites*, and several uncoiled Ammonite species. Amongst the echinoids the genera, *Discoidea* and *Cardiaster*, are represented, the former by a species close to *hemispherica*. Gastropods lamellibranchs and brachiopods also occur. The matrix is a hard, rather coarse sandstone and the state of the fossils is poor. In spite of this there is little doubt that they are from an horizon new to India and that they are of Gault age.

On his way back from the Khyber, Dr. Fox found some large blocks of yellow sandy limestone near Jamrud. They are thought to have come from the limestone scarp east of Shahgai. The interesting point about them is the fact that they are fossiliferous and contain *Productus* and *Spirifer*, which have been identified by Mr. G. H. Tipper as indicative of a Devonian facies.

During the year collections of fossils were presented to various Universities, colleges and schools throughout India. Casts of many of the principal Siwalik vertebrates were prepared and presented to museums abroad. The Library and collections of the Geological Survey have been used extensively by private geologists visiting Calcutta, to work out their own collections; as in the past every endeavour has been made to assist them.

Sub-Assistant H. M. Lahiri rendered valuable assistance in the work of sorting and classifying the material left by the late Mr. Vredenburg and in other ways. Since November his place has been taken by Sub-Assistant P. N. Mukherji.

MINERALOGY.

Cryptohalite and fluorite from the coal-fields.

During a visit to the Barari Colliery in the Jharia coalfield, Dr. Fermor noticed, on the surface of a collapsed area where seam No. 15 was on fire underground and where smoke was escaping at the surface, two efflorescences, one yellow and the other white. The yellow, which was in arborescent growths, proved to be native sulphur as expected. The white efflorescence was of greater interest, however, for it proved to be cryptohalite, a mineral hitherto recorded only from Vesuvius. Cryptohalite, which is ammonium silicofluoride, $2NH_4F.SiF_4$, occurs naturally, both amorphous and crystallised in the isometric system; in addition a hexagonal form has been prepared artificially. According to Dr. Christie the material from Barari contains all three forms. As the formation of this mineral suggested a combination of ammonia from the coal with fluorine from the mica-apatite-peridotite dykes, which are to be seen underground at Barari, Dr. Fermor revisited Barari and found that the efflorescence occurs by the side of a weathered outcrop of a mica-apatite-peridotite dyke on top of an uncollapsed pillar of the mine, and that both efflorescences are deposited from a white smoke immediately at its point of issue from the hot ground. Judging from information obtained from Mr. Bathgate of the East Indian Coal Company, to whom we are indebted for the collection of further supplies of cryptohalite, the carbonaceous shales overlying the coal seam are also on fire. It is possible, therefore, that these shales, rather than the coal itself, are providing the ammonia. At Barari, at any rate, we have an imitation of one of the phenomena of vulcanicity, for a burning coal seam is producing a result hitherto achieved in Nature only by Vesuvius.

Some years ago fluorite was found by Dr. Fermor in both the Talchirs and the granulites of the Bokaro coal field. It was obviously an added mineral, but its source was unknown. The Barari indication of fluorine in the mica-apatite-peridotite dykes and the fact that these dykes in the Bokaro coalfield are almost invariably weathered at the surface now lead to the suggestion that a portion of the fluorine removed

in the course of this weathering may have found a resting place as the fluorite of the Talchirs and granulites. When it is remembered that in other coalfields also these dykes are similarly weathered other occurrences of fluorite may be anticipated in the Gondwanas.

Lazulite from the Central Provinces.

Near Chikhla in the Bhandara district of the Central Provinces Dr. Fermor some time ago collected a curious rock containing two minerals that were doubtfully identified as sapphirine and enstatite.[1] The blue mineral is in grains too small for separation in sufficient quantity to render possible a chemical analysis, but Dr. Christie has succeeded in determining sufficient of its optical properties to indicate that the mineral is lazulite. This was confirmed by a micro-chemical test for phosphorus. By immersion methods the mineral was found to have the following refractive indices: $\alpha = 1{\cdot}615$, $\beta = 1{\cdot}635$, $\gamma = 1{\cdot}645$ (all $\pm 0{\cdot}003$) in sodium light. The mineral is optically negative. By heavy liquids the specific gravity was found to be 3·17. Both refractive indices and specific gravity are higher than those hitherto recorded for lazulite; this probably indicates the presence of a somewhat greater percentage of iron than usual. This is not the first record of lazulite in India; it had previously been found in Kashmir. The other mineral Dr. Christie found by similar methods to be either clinozoisite or kyanite.

Chabazite in Deccan Trap basalts.

Dr. Fermor has been able to confirm the genetic relationship that appears to exist between chabazite and chlorophæite, in the basalt of the Deccan Trap. In a doleritic flow rich in chlorophæite near Pipla in the Chhindwara district, it was found possible to detect minute chabazite crystals in cavities left after the brittle chlorophæite had been shaken out. Chabazite has now been found in this relationship to chlorophæite at three different localities, Bhusawal, Nagpur and Pipla. As chlorophæite is a common mineral in the Deccan traps it seems likely that chabazite will also prove to be widely distributed in this formation.

Ptilolite in the Deccan Trap.

As has already been recorded Dr. Christie found one of the zeolites obtained from the Bhusawal boring to be ptilolite,[2] this being the first record of this mineral in India. Mr. Crookshank has now found this mineral to be of common occurrence in zeolitic specimens from the Pipla tract of the Chhindwara district, and it seems not unlikely

[1] *Mem. Geol. Surv. Ind.*, Vol. XXXVII, p. 757.
[2] *Rec. Geol. Surv. Ind.*, Vol. LVIII, p. 162.

that ptilolite is widespread in the Deccan Trap formation as the common fibrous zeolite.

Tibet.

During the year preceding his death in 1923, Sir Henry Hayden, late Director of the Geological Survey of India, carried out, at the invitation of the Tibetan Government, a reconnaissance survey of the country to the north-west of Lhasa. With the kind permission of the executor to his will, Mr. A. A. Vlasto, I took the opportunity, while on leave last year, of making a careful search amongst Sir Henry Hayden's papers, in the hope of discovering some written account of his scientific researches and, more especially, any geological map recording his results. Most unfortunately, neither one nor the other could be found. As it was his intention to offer the results of his scientific researches for publication in the *Records* of his old department, I propose to attempt, with the help of my colleague, Mr. G. H. Tipper, the difficult task of constructing a paper out of his field-notes, which, fortunately, have come to light; this paper will appear shortly in the *Records*.

Both from a scientific and an economic point of view, Hayden's results were somewhat disappointing, but they none-the-less form a most valuable addition to our knowledge of the geology of a difficultly accessible area of the central Asian highlands. The reconnaissance was a continuation of his survey of the Tibetan provinces of Tsang and Ü carried out in 1903-04 and comprised the following itinerary.

Sir Henry Hayden was accompanied by the Italian guide, Cesare Cosson, who was afterwards killed with him in Switzerland, and by an Indian surveyor, Gujjan Singh, supplied by the Survey of India, who has produced an excellent and valuable topographical map of the country along the route followed. The party left Lhasa on the 10th of May 1922, and proceeded in a W. N. W. direction to a large lake known as the Kya-ring Tso, the south-eastern edge of which is just under 190 miles from Lhasa. The route followed the ascent of the Kyi Chu valley to the snowy range in which it rises and which includes the peak of Nyen-chen-thang, over 23,000 feet high. The snowy range was found to consist of granite, and the rocks intervening between this and Lhasa included a series characterised by large occurrences of rhyolite unconformably overlying quartzite and shale. The snowy range was crossed *viâ* the pass known as

the Go-ring La (19,000 feet)—in spite of a "very bad road up to glacier—over granite boulders all the way," and an "intense" wind all the way down from the Go-ring La in a march of from 20 to 22 miles. The path then crossed two rivers, the Tri Chu and the Ngang Chu, followed the valley of the Nya-tsang-sung-ngo, skirted the hills S. E. of Shen-tsa-Dzong, and passed through that town to the lake mentioned. From the Kya-ring Tso the travellers worked westwards, passed the Ngang-tsi Tso and its satellite the Phung-pa Tso, to another lake, the Tang-ra Tso. This was their farthest point from Lhasa, being distant some 290 miles as the crow flies.

The rocks between the Nyen-chen thang range and the Tang-ra Tso consisted almost entirely of two types, a grit series not unlike the Gondwanas and a limestone which appeared to be of Permo-Carboniferous age. One or two patches of Tertiary strata were seen, in one of which some impure coal was inspected.

Similar rocks were encountered on the way back by a slightly different route to Shen-tsa Dzong. From the latter town a north-eastern direction was followed between the large lake Tso-zi-ling and the smaller lake Pang gok Tso as far as Lhum-pho. The first half of this section of the journey, over hilly country, consisted mostly of the limestone, with smaller exposures of the grit series and one or two tongues of granite. The latter half traversed alluvium, with here and there low hills of Tertiary rocks protruding. At "Limba," which almost certainly corresponds to the Lhum-pho of the map, a fine dome of Tertiary rocks was seen with a vein of asphalt about 8 inches thick in the centre. Such a structure and seepage would, in a more accessible situation, offer considerable attraction to an oil company.

From Lhum-pho, which is about 190 miles N.N.W. of Lhasa, a somewhat sinuous route was followed back to the latter city past the smaller Pam Tso and the large lake of Nam Tso. The rocks as far as Phong-do Dzong were found to consist of the grits, with patches of limestone and bands of granite. Between Phong-do Dzong and the capital city the rhyolite series was again crossed.

ECONOMIC ENQUIRIES.

Building Materials.

See Limestone.

Cement Materials.

See Limestone.

Coal.

Bamra State Bihar and Orissa.

The authorities of Bamra, one of the Feudatory States of Bihar and Orissa, suspected the presence of coal in the south of the State. An investigation by Mr. H. Cecil Jones, however, failed to reveal any sign of this mineral.

Pench Valley; Central Provinces.

Whilst making a general inspection of collieries in the Pench Valley coalfield, Chhindwara district, Central Provinces in 1924, Mr. Hobson took the opportunity to obtain a number of coal samples from the various pits. These samples were subsequently analysed in the laboratory of the Geological Survey and the results submitted at the beginning of the year under report.

As a result of these sampling operations and the analyses it is found that the coals have a calorific value ranging from 6,515 B.T.U. down to 5,226 B.T.U. and that whilst the coal in the central portion of the field, which has been exploited to the greatest extent, is all non-coking coal, that in the western part of the field yields a hard coke. As one passes west, also, the seam worked is thicker and on the whole of a somewhat better quality.

The data on which to base any estimate as to the quantity of coking coal available is extremely meagre. Coal which gives a hard coke occurs on the east bank of the Kanhan River and again near Ghorawari to the east; between these two localities no sample could be obtained and a conservative estimate of the lateral extent of this coal would be two miles. East of Ghorawari the coal appears to yield a softer coke such as that obtained from near Kothideo and Kolia, and its lateral extent is increased by at least another two miles This area is marked by a series of east and west faults which continually bring the strata up to the north but there appears to be a falling off in quality. As a conservative estimate Mr. Hobson considers that a distance of 750 feet to the dip may be taken as the width of exploitable coal-bearing land, though no borings have been put down to test the coal on the dip side. The dip whilst steeper than in the central part of the field should admit of working this distance to the dip. In three pits the seam is worked for a

thickness of from 6 to 8 feet and the full thickness is stated to be from 9 to 20 feet. A figure of 10 feet may be taken for an estimate. Using this data the calculated total reserves of coking coal work out at 3,150,000 tons for each class or a total of 6,300,000 tons. The hard coke, derived from coal with an ash content of 17 to 19 per cent., is not pure enough to be used by itself for metallurgical purposes. The coal yielding the softer coke has an ash content of 19 to 19½ per cent.

Development work in the western part of the field is not yet very far advanced and only three samples could be obtained from this section. The mean analysis of these three samples, air-dried, was as follows:—

Moisture	2·26 per cent.
Volatile matter	29·00 „
Fixed carbon	50·34 „
Ash	18·40 „

From the central section of the field seven samples were obtained having approximately the same analysis, the average of an air-dried sample being as follows:—

Moisture	7·86 per cent.
Volatile matter	29·64 „
Fixed carbon	44·41 „
Ash	18·09 „

At the time the samples were taken simple field coking experiments were carried out to see whether the freshness of the coal had any appreciable effect on its coking properties. In some cases a slight caking effect was obtained in the field and not in the laboratory but on the whole these tests showed that, if the freshly cut material gives a coke, then coke is also obtained in the laboratory at a considerably later date. It is proposed to publish the results of this work *in extenso* shortly.

Kamasamudram; Madras.

The possibility of finding coal near Kamasamudram, a railway station on the Madras and Southern Mahratta Railway, seems to have impressed the Mysore Durbar to such an extent as to lead them to put down borings. A sample of shaly coal reputed to have

come out of one of the borings, was forwarded to the Geological Survey and yielded on analysis:

Moisture	1·85 per cent.
Volatile matter	41·90 „
Fixed carbon	30·76 „
Ash	25·49 „

The material caked strongly, giving a dark brown ash. The Mysore Durbar, who do not seem to have consulted their own excellent Geological Department, eventually called in the services of Major Hance, and at his suggestion appealed to the Geological Survey of India. Mr. Vinayak Rao, who was deputed to investigate the matter, confirms Major Hance's opinion that there are no Gondwana rocks in the neighbourhood, and that no coalfield is likely to be found.

Copper.

Yamethin district; Burma.

A trace of copper ore was noticed in association with galena on the hill 2 miles 5 furlongs N.E. of Kyatpye, in the Yamethin district of Upper Burma. It does not appear to be of any commercial value as an ore of copper.

Bundi State; Rajputana.

Old pits for copper were noted by Mr. A. L. Coulson in Bundi State, Rajputana, at Neagaon (25°30′: 75°34′): 2 miles west of Narenpur (25°28′: 75°32′), and one mile north-west of Gudha (25°31′: 75°28′) but the ores on prospecting were found to be not worth working.

Engineering Questions and Allied Enquiries.

Bridge Foundations; Ranchi district, Bihar and Orissa.

At the request of the Executive Engineer, Ranchi, Mr. J. A. Dunn was deputed to report upon several bridge foundations on the Ghagra-Simdega section of the Ranchi-Sambalpur main road.

The whole of the area is composed of the Chota Nagpur granite gneiss in general a hard and dense rock, but occasionally somewhat sheared, in which case surface decomposition may result in a soft, easily disintegrating material. The granite-gneiss varies from

a coarse to a quite fine-grained rock, and is occasionally penetrated by pegmatitic veins. Inclusions of epidiorite, varying to hornblende schist, and of felspathic schist are rare. The coarse-grained granite shows a tendency to decompose and disintegrate more rapidly than the fine-grained.

The Banki Nadi—mile 21½ from Lohardaga. The river here averages about 50 yards wide, flowing in the thick alluvium a portion of which connects the two south-flowing tributaries between which the road crosses the river. In order to avoid the construction of more than one bridge the bridge site must be limited to the stretch of river between these tributaries. To the west of the present road the alluvium in the river bed is apparently of some depth; the high banks with the bad lands on the south side would perhaps point to its being quite considerable. At the present crossing tests have not disclosed any rock down to a depth of 16 feet.

Between the present crossing and the Satbahini Nadi to the east Mr. Dunn reports there are two possible sites, one some 200 yards east of the crossing and another at the north turn of the meander immediately to the east. About 200 yards east of the crossing there is a small outcrop of granite-gneiss on the south bank of the river. This rock is somewhat decomposed immediately at the surface, but only to a very shallow depth, the granite below being a hard fine-grained material. The surface of the granite slopes to the N. of N.N.E. at an angle of about 10°. In consequence it seems likely that the depth of the granite surface would considerably increase towards the north bank. This would have to be tested. Of the two sites this is the more favourably located, as the river here is fairly straight and whatever current there is would swing against the south bank where the hard rock is at the surface. This site would also require the least diversion of the present road.

At the alternative site at the north bend in the meander there is a line of granite-gneiss outcrops extending almost across the river except on the north bank itself, but as the river is still cutting into this bank farther east it seems very likely that the granite will be at a very shallow depth. The river is here quite narrow. The abrupt turn in the river will throw a strong current against the north bank, but fortunately the site is just on the west or upstream side of the actual bend.

Streams between Gumla and Palkot. In all the streams between Gumla and Palkot there are good granite outcrops close to the

present road. Where decomposed at the surface, the granite should, of course, be excavated for a few feet in depth.

River 4 miles south of Palkot.—The river in this neighbourhood is about 60 to 100 feet wide. At the present crossing it is about 100 feet wide, the bank being about 3 feet high. Tests have shown that the alluvium extends down to a depth of at least 12 feet. At this site there is no sign whatever of any granite cropping out. Granite was found by Mr. Dunn in the river bed over ½ mile to the east, but a site so far away would mean a very long diversion of the road. About 300 yards west of the present crossing, however, granite crops out on the south bank. At this place the south bank is as high as 10 feet, the north bank being only 3 feet. In the centre of the river bed tests have shown the depth of the alluvium to be at least 6 feet. From the rapid slope of the granite surface on the south bank, the depth of alluvium may be considerable. The river here is only about 60 feet across. It is not possible to state the precise depth of the granite below the alluvium on the north bank, but it is proposed to wash-bore.

River 2 miles south of the previous locality, and just north of Pojenga. At the present crossing there is a small outcrop of granite in the centre of the river bed, but the alluvium is apparently quite thick on either side. A little farther upstream, however, fine fresh granite crops out across the river, and would afford the best bridge foundations.

Small stream at mile 74½ on the Kolebira-Biru section. The stream is a small tributary of a branch of the Halwai Nadi. The old culvert, built on sandy alluvium, was swept away by floods owing to insecure foundations. Downstream, only sand and loam occur in the stream bank. About 250-300 yards upstream, however, some granite was noted by Mr. Dunn crossing the stream-bed, and this should take any culvert quite well. It is rather far upstream for a good road-gradient in this hill-section, and the Engineer proposes to wash-bore at the present site; Mr Dunn, however, thinks the depth of alluvium may be considerable.

The Halwai Nadi, 2 miles S.S.W. of Biru. To the west of the present crossing only alluvium is met with as far as the Palamara River and there is no suitable bridge site. At the crossing itself, just on the north side, is a very small outcrop of granite, but in the river and on the south bank there is only alluvium which is apparently quite thick. The stream here is also rather wide,

East of the present crossing, however, granite was found cropping out on both sides of the stream and about 14 miles upstream there is a very favourable spot where the width is only 200 feet. The granite here on both banks is described as fairly fresh. The bed of the stream between the banks is in thick alluvium, but the irregular character of the denudation of the granite makes it impossible to estimate what the depth of the alluvium may be; it may be 20 feet, perhaps more, and the surface of the granite below may be decomposed for 3 or 4 feet or more. The central pier would naturally have to go to the granite surface, and only excavating or boring would show the depth of this. With such a depth of alluvium there should be no danger of scour on the actual foundation even with the very strong current which is said to come down this stream after heavy rain.

Khunti Toli Nadi, 2 miles farther south, just north of Bangru village. Only alluvium occurs at the suggested site. Granite occurs on the rise close to the village 200 yards to the south, and there is also an outcrop some distance up the southern fork of the stream to the east. There is, however, never much water in the stream, and the alluvium seems quite firm and shows no tendency to scour. The banks are quite high, showing as much as 15 feet of alluvium and the depth of the latter may be well over 20 feet. The engineer proposes to wash-bore in case granite may be met with at a shallow depth, but it is thought that, with due precautions the two culverts necessary might be quite safe on the alluvium.

Mr. Dunn concludes his report by remarking that throughout the length of the road examined the granite should make excellent foundations. The surface rock is generally somewhat decomposed, and where directly subject to a strong current is likely to scour, but if the foundations are sunk about 2 feet into the fresh rock this would be avoided. Granite below alluvium, it must be remembered, has been subject to decomposition by the overlying water, but no removal of the decomposed material by scour has been possible. All piers, therefore, must be taken through this decomposition zone and well into the fresh granite.

Dam-site; Chhankata, Singhbhum district, Bihar and Orissa.

At the request of the Deputy Commissioner of Singhbhum, Mr. J. A. Dunn was deputed to report on the location of a proposed dam in the Sanjai River immediately to the east of Chhankata village, a little over a mile from Sonua.

About ½ mile to the N. W. of Sonua village is a large tank, along the *band* on the south side of which runs the Sonua-Jate road. An old trench extends in a north-westerly direction from the tank to the river, and it is immediately on the south side of the point where this trench meets the river that it is proposed to erect the dam. The height of the proposed dam will be from 15 to 17 feet. It is proposed to divert the flood waters of the Sanjai into the tank for the purpose of irrigating the land to the south.

In the bed of the stream at the site of the dam is an outcrop of a peculiar indurated shale. With the exception of two or three very small quartz veins no more than ½ inch wide, the rock is uniform throughout and practically devoid of joints or fissures. The cleavage is very slight and dips 15° E. of N. at about 80°. The rock is considerably contorted here and there, but its homogeneity and poor cleavage prevent this from being a drawback.

Mr. Dunn notes that the strongest foundation will, of course, be obtained by an alignment parallel to the direction of the cleavage, hence slightly askew to the direction of the stream above the toe of the dam. The dip of the cleavage is upstream; this is also a favourable feature both in regard to the impermeability of the foundation and the direction of thrust. The rock itself, although indurated and dense, is not as hard as might be hoped, and if the proposed structure were to be of any considerable height with a high pressure on the foundation, the site would be unsuitable. But as the height of the structure is to be about 17 feet only, and the maximum pressure about 3 tons per square foot, the strength of the rock is probably considerably more than is required; it is suggested that this opinion be confirmed by a test. There is no likelihood of scour. Mr. Dunn notes that the northern 10 feet of the outcrop of shales in the stream-bed are rather more highly cleaved and fissured than the remainder of the outcrop, and for this reason thinks it would be advisable to keep the toe of the dam this distance downstream from the north edge of the outcrop.

Maniari reservoir; Bilaspur district, Central Provinces.

Mr. W. D. West was deputed to advise on certain questions regarding the reservoir in course of construction at Maniari in the Bilaspur district of the Central Provinces. A waste-weir site has been chosen at the S. W. end of this reservoir, and information was required as to (*i*) whether sound rock is likely to be obtained at a

reasonable depth under the soft and cracked rock at the left (east) flank of the weir, and if so at about what depth; and (*ii*) whether there is any reason to suppose that the rock in the centre and right flank of the weir is not entirely sound and is not connected with the solid stratum of rock which appears to underlie the whole area.

The site chosen for the waste weir is a small spur of granite running out into the alluvium in an easterly direction from the main granite hills on the west. It is bounded on the south by thick alluvium, and on the north by a small stream running east, which has cut its way down into rather altered granite.

Doubts as to the soundness of the site have arisen owing to the fact that the rock at the eastern end of the spur is of a different nature from that forming its centre and western end. Examination has shown that the former is an acid variety of the granite, differing chiefly in the complete absence of mica. In addition it has a somewhat fissile structure giving it a bedded appearance with a strike about 75°E. of S.

The junction between the two types is quite apparent, and, owing to the fact that the upper surface of the true granite slopes to the east and that the eastern end of the spur is somewhat higher than the centre, there has arisen the idea that the true granite dips under the acid variety in the manner of a stratified sedimentary deposit. The granite and its acid variety being igneous rocks there is no particular reason to expect that it may continue to dip eastwards under the acid variety at an angle the same as the surface slope of the granite as seen on the top of the hill. The latter is a purely denudation effect. It is much more likely that the junction is quite irregular; it may approach verticality.

To the east of this granite spur is the Maniari river, which passes mainly through alluvium but also reveals some granite. Further east still, however, is a narrow line of rock standing up out of the alluvium and running about 75° W. of N., a direction which is exactly in line with the acid rock at the end of the spur. Moreover it is of precisely the same rock with the same fissile structure, and, although it is not seen in the Maniari river, there can be little doubt that the two were once connected in the form of a long dyke cutting the granite.

An important point about this dyke rock is noted by Mr. West. At the top of the eastern end of the spur the rock is seen to be traversed by a fine network of veins of quartz, and the same feature

is seen in the continuation of the dyke to the east of the river. It is clear that this is due to the rock having been badly crushed at some time, the fractures being subsequently sealed up by quartz deposited in them, as is commonly the case with crushing due to faulting.

The rock thus suffers from two weaknesses, the fissile " bedded " structure, which is parallel to the length of the dyke and may have had some connection with the way it cooled; and this later crushing, which, although subsequently sealed up by vein quartz, will always be a source of trouble.

The rock, therefore, as already recognised by the engineers, is eminently unsuited for the construction of part of a weir, and, what is of particular relevance, it has been shown that both these weaknesses occur in the rock throughout its length, so that should the acid rock on the hill continue in depth, as is most probable, there is little likelihood that it will change into rock without these weaknesses.

It appears that if sound rock could be reached at or above R.L. 1160 then the present design and position of the weir could still be retained. As already pointed out, the slope of the top of the sound granite cannot be regarded as necessarily continuing thus beneath the unsound rock, and a careful examination of the north and south sides of the hill certainly suggests that the unsound rock continues in depth to below the 1160 limit, although the evidence is not absolutely decisive. Stronger evidence is afforded by the eastern end of the spur. All down this side the unsound acid rock can be seen actually in place, the lowest point being about R. L. 1130 or 1125, although of course it may go lower, and the whole of this would presumably have to be excavated. Thus there seems no chance of the required conditions being satisfied.

Mr. West has, therefore, recommended that further excavation at the eastern end of the weir site be stopped and the site moved further west. The rock in the centre and in the western side of the weir, as at present designed, does consist of the typical granite of the area and is certainly connected with the solid stratum that underlies the whole area. It is also probably quite sound, although it will contain the usual joints that are found in granites. In addition there is a certain amount of jointing in a direction 75° W. of N. to 75° E. of S., *i.e.*, along the length of the weir, which appears to be a direction of weakness throughout the area; this

appears to die out westwards and is not regarded as being a very serious factor.

Khyber Railway, N.-W. Frontier.

The heavy rains of 1925 appear to have been responsible for falls of the roof and subsidence in some of the tunnels of the Khyber Railway, particularly between the present terminus at Landi Kotal and the projected terminus at Landi Khana. The services of an officer of the Geological Survey having been requested for the examination of the hill-sides and tunnels of the line, Dr. C. S. Fox was deputed to carry out the investigation, Mr. E. R. Gee accompanying him for instructional purposes. The railway alignment has encountered massive bedded limestone and laminated shales with finely disseminated pyrite. Both types of rock, although showing a general regularity of strike and dip, were found to be intensely over-folded. In the case of the limestones from the Ali Musjid tunnels to Landi Kotal, the line can be assumed to be quite safe. According to Dr. Fox, the same can scarcely be said regarding the tunnels in the black and grey slaty shales. These rocks, occasionally crossed by zones of crush and shearing, owing to the presence of finely disseminated pyrite, are subject to rapid alteration on exposure to damp air. The pyrite is decomposed, and the sulphuric acid therefrom leads to the formation of alum, breaking down the shales into soft clay. The alum occurs as an efflorescence on the surface of the shales or in the tunnels which traverse these beds. After rain the efflorescence is washed away, but in the following dry weather more efflorescence appears. Thus it is that the shales, besides being decomposed into clay, are leached of a considerable volume of solid matter. The process must lead to a weakening of the strata, particularly in the tunnels, since the oxidation of the pyrite cannot be prevented, nor is it possible to prevent the soluble alum from being removed in solution. Unfortunately, the trouble does not end with the decomposition of the shale to clay, nor with the liberation of acid and formation and removal of alum. The sulphuric acid and the sulphate salts have a harmful effect on lime mortar, concrete, and portland cement, and the cementing medium is rendered useless and friable and the masonry weakened.

The best solution to the problem is, in the opinion of Dr. Fox, the use of blocks of quartzite or hard pure sandstone without any mortar. This method is considered impracticable in the Khyber

owing to the difficulty of procuring the quartzite. A reasonable degree of immunity, at least against the presence of sulphate salts, would appear to be possible by using a more suitable mortar, such as bauxite cement (*ciment fondu* or La Fargo Cement). Experiments have shown that bauxite cement sets quickly and at the same time to a higher strength than portland cement. It is specially claimed that bauxite cement is immune to the corroding effects of salt water or soils contaminated with sulphate salts. If these claims for bauxite cement can be substantiated, it is evident that the masonry of the tunnels in the pyritiferous slaty shales should be re-cemented with bauxite cement. This has been recommended by Dr. Fox, who considers that the hill-sides are safe, but that the trouble is, and will continue to be, the weakening of the shales particularly in the tunnel sections. The sections which need early attention have been pointed out. The re-lining of all the tunnels, which show an efflorescence of white (alum) salts in the tunnel and on the shales outside, should be carried out steadily on an extended programme, the case of those tunnels which traverse the shales along their strike being relatively more urgent than that of tunnels which cross the strike of the strata. Tunnels which cross zones of crush and shear in the shales require the earliest attention.

Dr. Fox has also discussed the effects of floods in the streams of alluvial tracts, such as those between Jamrud and Bagiari and about Zintarra. He recommends stream training by means of stone-aprons (masonry surfaces) gently inclined upstream, both in dip and strike, to the bed and banks respectively of the stream. Such control devices are best situated just above a concave bend or where a stream is to be deflected; they should be located on that bank which is subject to scour. The deflecting angle should not be more than 20° either in dip or strike to the direction of stream flow. A stream will thus be forced up the inclined plane, its velocity reduced, and its load of débris deposited, the water spilling back to the stream robbed of its scouring power.

Haro River dam-sites, Punjab.

At the request of the Superintending Engineer, Hydro-Electric Circle, Punjab, Dr. G. E. Pilgrim was deputed to investigate and report upon proposed dam sites in the Haro River where it leaves an open alluvial plain and enters high rocky hills just before reaching the village of Sanjwal, some 4 miles E. S. E. of Campbellpore. Two sites had been sug-

gested, one of them, the lower site, parallel to the strike of the rocks and the other, some 300 yards higher up stream, running across the strike.

According to the report Dr. Pilgrim has submitted, the majority of the rocks are of limestone with occasional shaly bands amongst which is one prominent bed of purple shale. The lithological resemblance of certain of the beds to the basal nummulitic beds of the Pir Panjal and the occurrence in them of similar small foraminifera, leave it hardly in doubt that all the rocks belong to the Hill Limestone stage of the Kala Chitta Nummulitics. The total thickness of strata exposed in the river section is about 350 feet, of which about 60 feet are massive limestones. These are underlain by thin-bedded limestones, with some bands of shale, a prominent bed of purple shale being amongst the lowest beds exposed. These are perhaps about 170 feet thick. The massive limestones are overlain by thin-bedded shaly limestone and shale, of which about 120 feet are exposed. This series of strata is crossed four times between the bend in the river and a point about 300 yards below the lower dam site, where the beds become almost horizontal. This is due to the fact that there are five folds between the Sanjwal ridge and the point below the lower dam site mentioned above. From Sanjwal village down to the bend in the river the strike of the beds is approximately E.-W. and follows the course of the river, which thus flows along an anticlinal fold, Sanjwal ridge forming a synclinal basin, bed after bed coming to an end east of Sanjwal village. At the bend in the river the strike curves sharply from an E.-W. direction to a S.E.-N.W. direction, and then very gradually resumes its original direction.

North of the Sanjwal synclinal ridge the rocks disappear beneath a large area of cultivated ground. These alluvial beds are well seen in the bed of a large stream about one mile west of Sanjwal village and about the ground to the west of this stream. They consist of a fairly compact silty sandstone or clay, with bands of soft but more compact sandstone as much as 2 feet thick in places. The highest member of the alluvial series is a conglomerate with large pebbles, which is frequently encrusted with calcareous tufa. At Jessian, about three miles to the west, this conglomerate caps many of the hills and is as much as 30 feet thick; but in the area now dealt with Dr. Pilgrim only noticed it in a small exposure to the east of the village of Sanjwal. Besides the area of cultivated ground to

the north of the Sanjwal synclinal, referred to above, there are other areas of cultivation to the west of the lower dam site, which no doubt represent alluvial deposits of a greater or less depth. From observations at Jessian and elsewhere, it was evident that the alluvium fills up valleys between the solid rock formations, which are often of considerable depth; from which it follows that the alluvium thickens very rapidly from the nearest visible outcrop of solid rock. The significance of this from the point of view of the construction of a masonry overflow is of some importance.

Although only two sites were suggested for a dam, three distinct projects arise for consideration on these two sites. On the lower site it is possible to build: (1) a gravity dam across the narrowest portion of the gorge, resting on and, so to speak, continuing the massive limestone rock which forms vertical walls on either side of the river; (2) an arch dam springing from two haunches of massive limestone on either side of the river. On the upper site no such haunches of solid rock exist so that a dam constructed in this position must necessarily be of the gravity type (3).

A dam which runs parallel to the strike of the rocks is *primâ facie* to be preferred to one which runs across the strike. In the latter case the bedding planes which offer opportunities for the water to percolate to and so weaken the foundations of the dam are numerous; in the former, on the other hand, the bedding planes are few in number and the danger of percolation is diminished. Although in the present instance the substance of the thin-bedded limestones and shales, which would form the greater portion of the floor against the upper dam site, is not itself permeable, the thin-bedded character of the rocks offers a possible source of danger. Other things being equal therefore, the lower site is to be preferred. Apart from the question of expense, another objection exists, in the opinion of Dr. Pilgrim, in the case of the upper site, which may tend to weigh down the balance in favour of the lower site. This is that by choosing the upper site the reservoir will be deprived of a very important portion of its storage content, and, moreover, since that portion of the reservoir to the north of the Sanjwal ridge communicates with the Haro by a stream which cuts through the ridge to the west of the upper site, it will be necessary to construct a massive *band* to impound the water in this northern portion. The massive limestone in the places where it lies in its original bedding planes, that is to say, where it is not folded, appears to be reason-

ably free from fissures, and its compact and massive character renders it eminently suitable to withstand great pressures and to form a secure foundation for any masonry structure. Unfortunately at the lower dam site the limestone is sharply folded both along and across the strike, and, as might be expected, is badly fissured. On either side, as one leaves the folded zone, the fissuring seems to be absent. It might be possible to construct a gravity dam here against the limestone walls with the aid of extensive cement grouting were it not for the fact that on account of the sharp bend in the strike at this point the zone of fissuring must extend far below the river level where grouting would be impossible. Such open fissures would be a certain source of leakage from the reservoir if not of actual danger to the stability of the dam.

Dr. Pilgrim considers that an arch dam might, however, be built so as to spring from the massive limestone cliffs outside the fissured zone, that is to say, from a point about 130 feet from the right bank of the river and from another point about 350 feet from the left bank of the river. These limits might perhaps be relaxed provided all visible fissures were grouted with cement, since an apron of impermeable rock interposes itself between the concealed fissured limestone and the reservoir, as the ground rises on either side away from the river. For the same reason in other parts of the reservoir which come into contact with the massive limestone it would only be the upper levels of the water which would actually touch it, since the impermeable thin-bedded limestone extends a long way up the hill sides. The smaller hydrostatic pressure in this case would be insufficient to cause serious leakage. Subsequently, if found necessary, visible fissures could be grouted in such parts of the reservoir.

Dr. Pilgrim considers that the formation as a whole would afford a sufficiently stable foundation for the base of the arch dam, the stability of which would not be impaired by leakage at its base since this part of the rock formation appears to be reasonably impermeable to water.

With regard to the location of an overflow for the reservoir, Dr. Pilgrim prefers a site about 5 furlongs west of Sanjwal village where the cultivated ground mentioned above rises to a crest of about 1163 feet elevation. To the west of this crest the ground falls to the stream mentioned above. The topmost level of the water will just reach this crest, and it constitutes an eminently

suitable site for an overflow into the stream referred to. The only difficulty concerns the depth at which the solid rock lies beneath the alluvium, on which the masonry foundations of the overflow should rest. Information on this point could be gleaned from trial pits.

Should the alluvium be too thick to make the construction of an overflow practicable on the line suggested, an alternative line exists, 400 feet to the N.E. On this line it is certain that rock exists a short distance beneath the surface. The objection to this line, however, is that the water from the overflow will naturally follow the course of a small stream, which will bring it into the Haro at a point too near the tail-race of the Hydro-Electric Power Works which it is proposed to erect. It will, therefore, be necessary to cut a channel through an outcrop of limestone to the south and lead the water from the overflow into the Haro at a point which is farther away from the tail-race. The expense of this would to some extent be compensated for by the limestone which would thus be rendered available for building the dam.

From a geological point of view the disposition of the strata render the construction of an arch dam on the lower site preferable to a gravity dam on the upper site, and the larger storage obtained tells in favour of the former project.

Mukerian-Mandi Railway project; Punjab.

On the alignment of the projected Mukerian-Mandi Railway there is one section for which two alternative alignments have been proposed. This section is situated from 2 to 3 miles east of the village of Talwara in the extreme eastern portion of Survey Sheet 248 N.E. (scale 2 inches=1 mile). At the request of the Superintendent of the Hydro-Electric Circle for the Punjab, Dr. G. E. Pilgrim was deputed to visit the site with the object of investigating the respective geological merits of the two alignments. According to him the geological formations exposed in the area consist of :—

(1) A series of massive but soft sandstones occurring in bands, having an average thickness of about 60 feet, interbedded with softer silty sandstones and arenaceous clays occupying an average thickness of 20 feet between each band of massive sandstone. These beds belong to the upper part of the Pinjor stage of the Upper Siwaliks.

(2) A boulder gravel which caps the preceding stage of sandstones and clays and occupies only the highest summits

of the range which rises between the Beas river and the Khad Ghamir, and occasionally small scarps which occur on the slopes down to the Khad Ghamir. This is never more than about 10 feet thick and belongs to the Boulder Conglomerate stage of the Upper Siwaliks. The strike of these beds is seen to bend round from N.N.W.- S.S.E. to N.N.E. S.S.W. The beds are disposed in a sharp synclinal fold, having its axis approximately in the bed of the Khad Ghamir. The dip of the beds both to the east and west of the axis increases rapidly from the horizontal to a maximum of about 40°.

(3) A series of horizontally bedded gravels of sub Recent age and derived from the disintegration of the boulder conglomerate mentioned above. These occupy the flat plateaus round Talwara about 50 feet above the bed of the Beas and also extend some way up the slopes of the hill-sides.

To consider first the original or more northerly alignment proposed which hugs the S. bank of the Beas, the first $2\frac{1}{2}$ miles are either along the low ground just above the flood level or on the gravel plateaus. As the point is neared where the hills adjoin the Beas, the alignment passes over the lower gravel slopes. So far no difficulty occurs since the gravels are stable and will form a sound embankment. The real difficulty begins when the Upper Siwalik beds run out to the river and affects a distance of about $\frac{1}{2}$ mile. This portion of the alignment is almost at right angles to the strike of the beds, so that the conditions making for geological stability are all that can be desired, provided the rocks themselves afford a sufficiently secure foundation for the line. Unfortunately this is only partially the case. The bands of massive sandstone, which form spurs jutting out into the river are, though soft, free from fissures and compact, and it is not anticipated that any danger is to be feared to that part of the line which may rest on this or to the concrete foundations which may be constructed on this as a base. The sandstone is even less liable to disintegration by water than by atmospheric agencies, as is shown by the spurs jutting far out into the river. Dr. Pilgrim, however, recommends that blocks one foot cube be subjected to immersion in water and to alternate exposure to a stream of water followed by desiccation in the sun at

intervals of 24 hours, during a period of a month, in order to make sure that no deleterious change takes place.

The state of affairs is, however, very different in the case of the softer silty sandstone and arenaceous clays which it has been stated are interbedded with the massive sandstones. The silty sandstones readily break down into a loose sand, where they are exposed to air, though even in their case the disintegration is more rapid under atmospheric agencies than under water. The clay bands are liable to erosion by water, and in consequence the whole stretch composed of the two elements, clay and sandstone, is worn away and a series of small stream-courses is produced between the bands of massive sandstone, while the river embays in such places between the projecting spurs of massive sandstone. It is, therefore, obvious that no reliance is to be placed on this part of the formation as a base for foundations of any kind.

Either wedge-shaped concrete revetments may be used to bridge over the stream courses, or steel culverts may be employed to connect successive ridges of massive sandstone, whichever is found to be most economical or desirable from an engineering point of view. The massive sandstone may be regarded as strong enough to stand the weight or to afford a secure foundation, while at the same time no apprehensions need be entertained for the cuttings, or in one case the tunnel, which will in every case be necessary to carry the line through the sandstone spurs, providing the experimental tests suggested produce satisfactory results.

If the weak places referred to above are ensured, Dr. Pilgrim considers there is no reason why this alignment should not be satisfactory.

Proceeding to the consideration of an alternative and somewhat longer alignment proposed by Major Anderson, we find that from the point where it diverges from the original alignment it passes over a sub-Recent gravel plateau and then ascends for the most part over superficial gravels until near the village of Nagrota. Beyond the steeper gradients involved and the greater amount of embanking necessary, there are no difficulties from a geological point of view up to this point. From now on the alignment gradually descends to the Khad Ghamir traversing three broad compound stream-courses which run down into the Nala Ghamir. This portion of the alignment is along the strike of the rocks, which dip at angles of from 20° to 30°, and thus correspond approximately with the angle of slope of the hill side. Owing to the denuding action of atmospheric agencies, the massive

sandstone has only been preserved for the most part on the spurs between the various tributary streamlets which run into the Khad Ghamir. The streamlets themselves are carved out of the soft silty sandstones and clays, which in the case of the area we are dealing with underlie the band of massive sandstone. According to Dr. Pilgrim, in three parts of the alignment it runs for distances of one to two furlongs practically on these softer rocks and over the whole of the hill-side these have disintegrated into sand, clay and soil. The geological conditions, therefore, are most favourable for slips of these loose collections of débris on to the alignment, while the slopes below the line being often very steep are also insecure. The junction between the massive sandstone is in general a precipitous cliff perhaps only 10 feet but sometimes as much as 80 feet in height.

In order to carry a railway line safely through country of this nature it is necessary that extensive revetments be made both above as well as below the line and a considerable amount of earth work banked up. If the expenditure of considerable sums on revetting and embanking is considered no objection Dr. Pilgrim, thinks that the unfavourable geological conditions can be successfully combatted.

With regard to the respective merits of the two alignments the question seems to be more one of expense than of anything else. In the first scheme there are numerous small intervals between the massive sandstone spurs to be bridged and numerous small cuttings to be made. In the second scheme the alignment is slightly longer and steeper and heavy revetments, high embankments and a few long cuttings will be necessary. It is thought that the second scheme would cost somewhat more in upkeep.

Building sites, Bakloh Cantonment ; Punjab.

A site selected for married quarters near the Tytler Lines at Bakloh having been abandoned on account of land-slides, the Geological Survey were appealed to for assistance, and Mr. E. J. Bradshaw was deputed to report upon the stability of alternative sites.

The Bakloh cantonment is built upon a ridge of Tertiary rocks consisting of dark, indurated, compact, and sometimes micaceous sandstone with intercalated beds of friable ferruginous shales. The sandstone is very freely jointed, so that it is usually possible to break off rectangular blocks of any size. This free jointing results

in the separation of large, irregular boulders at almost every outcrop. It is the combination of the clastic nature of the sandstone with the friable and slippery quality of the underlying shales which is the cause of the general instability of the area.

During heavy rain, small streams of water either eat back from the edges of the terraces over which they drain, or else find their way through the joint-planes of the sandstones and wash away the underlying shales; the result in both cases is the isolation of large boulders and masses of rock which are left in a state of gradually increasing instability.

The dip of the rocks in the cantonment is variable, but produces the general form of a syncline. The average dip on the west side of the Tytler Lines is about 35° to the north-east, while the dip on the east side is steeper and about 65° to west-south-west. Mr. Bradshaw remarks that while, in general, areas of steep dip are the most likely to give trouble through fracturing of the sandstone and the fall of boulders, yet the question of dip is of less importance than usual on account of the free jointing of the sandstone which is common to the whole area and is the immediate and governing cause of slipping.

It may be said at once that the whole of that portion of the Bakloh Ridge on which the Tytler Lines are built is unstable and, where there are no protective works, will be subject to removal piecemeal. The whole area is treacherous, and there is no building site which can be regarded as naturally and permanently sound. It is thought possible, however, to select sites which can be rendered reasonably secure by building protective works; these should primarily take the form of adequate drainage.

The general considerations which should govern the choice of any building site in the area are summarised by Mr. Bradshaw as follows:—

(1) Sites should be chosen on spurs rather than in re-entrants; re-entrants into which the surface water drains from every direction should especially be avoided.

(2) Ground which is overlooked by steep scarps may itself be sound, but there is, of course, the danger of material slipping from above.

(3) Ground where the slope of the hill-side is low is usually stable.

(4) Ground which has a large catchment area above it should be avoided unless the water drains naturally to the sides and not over the ground.

(5) Where firm ground can be found in the neighbourhood of a permanent stream-course, the construction of artificial drainage will be facilitated; but, if the ground is not firm, the proximity of a stream-course is a danger, and the site should be avoided.

(6) Springs on or above a site are a source of danger, and their immediate neighbourhood should be avoided.

The most important criterion regarding any site selected for building purposes is that it should be adequately drained. A suggested scheme of drainage for terraces was put forward by Mr. Bradshaw, who notes the following chief points :—

(1) Drainage should not be confined to the site alone. The ground both above and below each terrace should also be drained thoroughly.

(2) Both the slope behind the terrace and the lower face of the terrace itself should be supported to a height of about 5 feet by porous retaining walls, either of open-masonry or with weep-holes. Short wing walls might have to be built in some cases where terraces have to be excavated in the hillside.

(3) Drains of adequate capacity should run *immediately at the foot* of these retaining walls. It is important that the drainage should not be skimped or curtailed. The water should be led away quite clear of the ground immediately below the terraces.

(4) The terrace should have a gutter at the front edge of the terrace, so that surface water sould be carried to the sides and prevented from spilling over the face of the terrace.

(5) An adequate catch-drain or drains should be provided in the ground above the site to divert the surface waters well clear of the sides of the terrace.

(6) Where there are large stream-courses close to the terrace they should be cascaded where possible and sharp corners eliminated from the near vicinity of the building site.

(7) A small drain leading into the front gutter should surround the building itself so as to carry off water from the roof.

(8) If any small channels run naturally across a site, they should be diverted from above by lateral drainage.

Owing to heavy rain during the greater part of his visit, Mr. Bradshaw had the advantage of seeing the ground actually water-logged. Several small slips occurred while he was there, and the problem of the relative stability of different parts of the area was greatly simplified and in part solved by the manner in which the different sites withstood the severe rainfall.

The actual problem was to find sites for eighty-five married quarters. A block of ten quarters requires a terrace roughly 130 feet by 30 feet, and a block of five quarters one 70 feet by 30 feet.

It was decided that the majority of the quarters should be built on site No. 1 in spite of the disadvantage of its distance from the parade ground. The first block of ten quarters is to be situated on a spur below a telegraph pole on the road. This ridge is comparatively dry and stable, and the dip of its rocks is from 60° to 65° to the west-north-west. There is overhanging ground which is not stable but any fall would be broken by the terrace behind the site chosen. When the site is terraced, the front face should be supported by a retaining wall.

Two blocks of five quarters, staggered and *en echelon*, are to be sited on a similar spur close to that which has just been described. The same remarks apply as in the case of the first site.

Further along the road, the gentle slope of the hillside is broken by a series of low terraces. In this locality it is proposed that six blocks of ten quarters each should be situated. The dip of the rocks is 60°-65° to the west-north-west. The ground is stable, and consists of large boulders imbedded in firm soil. There is a considerable amount of surface water, but there will be no difficulty in leading it into the large stream-course near by. Great care should be exercised in ensuring that the water which irrigates the cultivated terraces above is all diverted clear of the site. The drainage of the road also should be improved.

Another site is below the hospital, and provides room for two blocks of five quarters each. The ground is firm, and should be drained into the neighbouring water-course. The road above should be drained adequately, and the small spring in front of the site should be avoided.

A further site was considered unsuitable for married quarters, chiefly on account of the proximity of the Isolation Hospital, but the area should provide a good site for any other buildings which may be required in the future. It lies on the crest of a steep and narrow ridge where micaceous sandstones and slaty ferruginous shales dip west-south-west at 65°. The ground is firm, and there is the advantage of the presence of several ready-made foundations available *in situ*.

Another site occupies the top of the western side of the ridge. The dip of the rocks is comparatively low, being north-east at about 30°. The rocks are the usual sandstones and shales, the actual sites being on shale. Here there are two terraces suitable for building on, provided they are adequately drained. The adjacent water-course would have to be cascaded, and there are some sharp corners in its course which ought to be eliminated, especially that just above the terraces. The terraces should be supported by retaining walls. For disciplinary reasons, this site was not considered suitable for married quarters, but, like the preceding, it provides a good potential situation for any other building which may be required in the future.

In Mr. Bradshaw's opinion, none of the sites is ideal, but, provided thorough drainage is carried out on the lines suggested, the sites could be made reasonably secure and stable.

After the buildings have been constructed, the first period of heavy rain will provide an opportunity for judging the efficiency of the drains in carrying all surface water clear of the terraces. As the stability of the terraces depends entirely upon the efficiency of drainage, additional drains should be constructed wherever the drains built are demonstrated to be inadequate to keep the terraces firm and dry.

Bhakhra dam ; Punjab.

Since 1915 the question of establishing a large dam 380 feet high in the Bhakhra gorge of the Sutlej river has at one time or another been referred to this Department for opinion. In 1925 the galleries laying bare the strata in the gorge, which had been recommended by the Geological Survey, were at last completed. Dr. C. S. Fox was instructed to examine the rocks in these galleries on his way back from the Khyber. The rocks in the narrowest part of the gorge, in the section selected for the site of the dam are somewhat crushed by sheir forces, evidently

the result of the weight of the beds in the steep hills on either side. There are potentialities, explained in the report submitted by Dr. Fox, for a landslip to occur just below the narrowest part of the gorge, owing to the strata being inclined down stream at high angles and striking across the gorge, almost at right angles. It is possible by going somewhat above the narrowest point of the gorge to find a place on which it would be safe enough to found a large dam. This place is roughly 300 feet above the previously selected site. On account of the steep hill-sides, however, it appears wise not to cut a permanent, side spillway in the flanks of the gorge. Through the ridge on the north side of the gorge Dr. Fox has pointed out the alignment of a tunnel which might function as a spillway. With due precautions the Bhakhra gorge is not considered unsuitable as the site of a large dam.

Landslides; Kalimpong division, Bengal.

At the request of the Forest Department of the Government of Bengal for an investigation of several landslides in the Kalimpong Division, Mr. E. R. Gee was deputed to visit the areas affected. Some of the landslides visited were situated within the Government Forests, causing the destruction of jungle over considerable areas. Others in Khas Mahal districts affected both the jungle and arable land, preventing the cultivation of the maize and rice crops which are grown extensively on these hill-slopes.

The areas, which, up to the present have been affected by the landslides include parts of the Rissum, Labha, Pankasari, Ambiok, Chumang and Pugo Forest Blocks; and the Chibo, Dolepchan, Ambiok, Pala, Pagag, Nim, Pagrenbong, Nimbong, Nobgong, Yangmakum, and Suruk Khas Mahal areas.

The strata concerned in the slides include the following formations:—

(1) The Coal-bearing Gondwanas, including felspathic grey and green sandstones with thick grey-green clays and several coal-seams.

(2) Slates and phyllites of the Daling division.

(3) The Gneissic series.

All the Gondwana strata have been severely crushed, the sandstones becoming markedly jointed, and the clays, together with some of the coal-seams, converted into flaky shales. In a similar manner

the clays and phyllites of the Daling division have become finely foliated and traversed by numerous planes of fracture. The angle of dip is usually very steep.

As a result of weathering the rocks have disintegrated rapidly, the original slope of the hillsides representing the angle of repose for unweathered rock. This factor combined with the fact that erosion has made the present slopes steeper than the original, has resulted in the instability of various parts of the division. The disintegration of the rocks, and therefore the mode and extent of the slipping, obviously depend on the nature of the strata affected.

Mr. Gee remarks that, in the case of the gneisses and micaceous schists, their rapid weathering appears to be due to the softer schistose intercalations, combined with the marked jointing of the harder gneisses. The disintegration of these gneissic outcrops being comparatively slow the landslips are of an intermittent nature depending on the rate of weathering of these harder gneisses. Attempts should therefore be made to protect these more resistant rock outcrops, so as to keep the intervening slopes of softer rock stable for a period sufficiently long of permit to the proper afforestation of the slide and the neighbouring slopes. Considering the denseness of the jungles of the division the importance of this factor is very considerable. Measures to further the stability of the harder outcrops might be in the form of stone pavements and revetments; or, in those cases where the exposures in both harder and softer rock are sufficiently sound, a low dam across the stream is suggested by Mr. Gee as likely to yield better results.

In the case of the shales and phyllites similar methods might be used where any resistant outcrops of quartzite or sandstone occur In other instances, however, in order to prevent effectively the continuance of the slip, the protection of the main drainage channels through a considerable distance would be necessary. In any case the afforestation of the more stable portions of the slide and of the neighbouring slopes should be carried out, and cattle-grazing disallowed.

In the case of the landslides of the Gondwana areas, outcrops of resistant silicified sandstones sometimes occur, but their strength is discounted by the jointing which characterises them. In the Pugo Landslide any such rocks have been so shattered that they offer little opportunity for protection, and afforestation, wherever possible, appears to be the only practical solution.

Mr. Gee has gone into the whole question with commendable care and submitted a useful report which the Government of Bengal has published.

Galena.

See Lead.

Gold.

Mr. Vinayak Rao reports that an adit driven by a prospector into the low hill west of Kuditanapalli village shows a quartz reef about 4 feet wide at the entrance and widening out in the cross-cut about 200 feet further on. The adit has been abandoned owing to the low percentage of gold.

North Arcot district; Madras.

Major Cunnynghame-Hughes is stated to have found gold at Rohera (24° 37′ : 73° 0′) in Sirohi State, Rajputana. Mr. Coulson inspected two old pits about 2 miles north-north-west of Rohera but could find no trace of either gold or pyrites. He was given a specimen said to have been taken from one of the pits about 25 years ago, but it contained only the following minerals:—pyrite associated with a little chalcopyrite, quartz, muscovite, sillimanite and accessory apatite.

Sirohi State; Rajputana.

Graphite.

A very small quantity of graphite was observed by Sub-Assistant B. B. Gupta in a vein intersecting gneissose granite in the stream-course 2¼ miles E. S. E. of Yeu, in the Yamethin district of Burma.

Yamethin district; Burma.

Iron.

Hæmatitic iron ore was found on the hill 1 mile 5 furlongs S.E. of Kundaw in the Yamethin district of Burma. The ore appears to have originated from a metasomatic replacement of the quartzites, and is associated with galena.

Yamethin district; Burma.

Mr. Coulson notes that iron ores have been recorded in the Bundi State, Rajputana, from Loharpura (25° 28′ : 75° 42′), Bhaironpura (25° 31′ : 75° 45′), and a second village named Loharpura (25° 33′ : 75° 58′). The ore occurs at the junction between the Jhiri shales

Bundi State; Rajputana.

and the Upper Rewah sandstone. In the Gwaliors old mines occur at Umar (25° 41′ : 75° 30′), Khenia (25° 20′ : 75° 25′), Narenpur (25° 28′ : 75° 32′) and Datunda (25° 27′ : 75° 30′). The ore consists of impure limonite and hæmatite derived from solutions accompanying the reef-quartz. The supply and quality of the ore is totally insufficient for modern purposes.

Mewar State; Rajputana.

In the remote past large quantities of iron were extracted from the highly ferruginous quartz breccia which is of common occurrence among the rocks of the Jahazpur and Sabalpura areas in the Mewar State of Rajputana. The workings have long been abandoned on account of the comparative cheapness of imported iron. There are still immense quantities of the ferruginous breccia *in situ*, but the extraction of the iron must necessarily be unprofitable in view of the dearth of fuel for smelting. Wood was used in days gone by, but the amount now available is quite insufficient for the purpose, and Mr. Bradshaw, who visited the areas, considers that there are no immediate prospects of successful economic development.

Kaolin.

Yamethin district; Burma.

The exploitation of the china clay E. of Indawgyi in the Letkakwe Stream about 6 miles south of Myohla in the Yamethin district of Burma (*Rec. Geol. Surv. Ind.*, vol. LI, pp. 14-15) has not proved commercially successful.

North Arcot, Madras.

Kaolin in small quantities was noted near Kuditanapalli about 2 miles north of Gudupalli railway station in the North Arcot district.

Bundi State, Rajputana.

Mr. Coulson found kaolin at Manak Chok (25° :3′ : 75° 57′) in the Bundi State, Rajputana, at the junction of the Jhiri shales with the Upper Rewah sandstone. It was of very poor quality and economically worthless.

Kyanite.

(*See* Sillimanite.)

Lead.

Southern Shan States.

During the latter part of June 1925 Mr. E. L. G. Clegg was deputed to examine an area in the Mawson or Bawzaing State of the Myelat division of the Southern Shan States and to collect samples of lead ore and lead slag from the locality. The area has been previously described by E. J. Jones[1] and C. S. Middlemiss[2], and Dr. Coggin Brown has recently summarised their reports.[3] It consists of rocks of the Plateau Limestone formation, a series of dolomitic limestones, probably of lower Palæozoic age, having intercalated in them lenticular arenaceous beds grading into purple shales. The limestones are slightly fossiliferous but no specifically identifiable forms have as yet been extracted from them. The dip of the limestones varies and, although a south-westerly one prevails, in many localities the limestones are seen to be almost horizontal.

The area is at present under development by Messrs. Steele Bros. and the Shan States Silver Lead Corporation; two mining leases however are still held over small areas by local inhabitants.

Mining was originally carried out by Chinese and Shan miners and the lines of old workings which are reputed to be more ancient than those of Bawdwin in the Northern Shan States, cover an extensive area and run in a direction 10°—15° W. of N., the general strike of the geological features of the Shan Plateau. Mineralisation has apparently taken place in a series of more or less parallel and intersecting veins, fissures and joints along this strike and can be traced southwards for a distance of more than 33 miles.

In one old working which Mr. Clegg examined half a mile S. W. by S. of the village of Pakin, the occurrence of galena in yellow clay approximates to that of an irregular stock-work, whilst in the Bawsaing Mine of the Shan States Silver Lead Corporation the ore occurs as an elongated and irregular lenticle replacing what seems originally to have been shattered and brecciated limestone.

Silver was the only mineral in which the ancient Shans and Chinese had any interest, and in various localities, in which smelting was carried out, are quantities of lead slag in which the percentage of

[1] *Rec. Geol. Surv. Ind.*, Vol. XX, pp. 191-194.
[2] *Gen. Rep. Geol. Surv. Ind.*, 1889-1900, pp. 122-153.
[3] *Rec. Geol. Surv. Ind.* Vol. LVI, pp 90-91

lead runs as high as 43. The slag is disseminated through the soil cap and is at present being exploited by Messrs. Steele Bros. who ship it to Europe as an ore of lead.

The following analyses of concentrated ore from the Bawsaing Mine of the Shan States Silver Lead Corporation and of slag from the localities cited were carried out in the laboratory of the Geological Survey of India :-

LOCALITIES.

A. Lead slag from 1 mile west of Pakin.
B. Lead slag from Ywahaung village.
C. Lead slag from ½ mile east of Tethein village.
D. Lead slag from Naung Lwe.
E. F. } Lead slag from bags in Messrs. Steele Bros.' godown at Heho.
G. Lead ore concentrate from the Bawsaing mine of the Shan States Silver Lead Corporation.

LEAD SLAGS.

Dry Assays.

	1. Per cent.	2. Per cent.
A	40·36.	40·10.
B	37·00.	35·56.
C	41·18.	39·56.
D	23·04.	24·38.
E	36·50.	36·26.
F	38·22.	37·28.

Average 35·70 per cent. of lead.

Wet Assays.

	Per cent.
A	40·83.
B	38·375.
C	39·837.
D	24·319.
E	37·08.
F	36·344.

Average 36·247 per cent. of lead.

ORE CONCENTRATE, BAWSAING MINES.

Dry Assays.

	1. Per cent.	2. Per cent.	3. Per cent.
G	70·04	70·12	69·76

Average 69·97 per cent. of lead.

Wet Assays.

G. . . . 72·575 per cent. of lead.

Silver in oz. per ton.

1.	2.	3.
15·626	15·05	15·196

Average 15·287 oz. per ton of ore concentrate.

The analyses of slag call for some comment as it will be seen from the tables that, whilst that from one locality yields only 24 per cent. lead, all the other localities show percentages of 36 and over. This probably explains the greatly varying analyses which Messrs. Steele Bros. Ltd. have experienced in successive shipments to Europe, and it appears as though a systematic sampling of the lead slags from the various collecting localities in the area would greatly benefit the exporters, since at present a shipment of lead slag having a high lead content is purely fortuitous.

Yamethin district; Burma.

Galena has been obtained in quartz veins intersecting the Chaung-Magyi series in the following localities in the Yamethin district of Burma :—

1. $2\frac{1}{2}$ miles E. S. E. of Dathwe.
2. $3\frac{1}{2}$ miles N. E. of Sedo in a tributary of the Mellang Chaung.
3. $2\frac{1}{2}$ miles N. E. of Kyatpye; this is not *in situ*, but the parent rock is probably 1 furlong S. E. of △ 2641.
4. $2\frac{1}{2}$ miles E. S. E. of Yeu in a granite vein in the stream-course; this is not *in situ*.
5. On the hill 1 mile 5 furlongs S. E. of Kundaw; in association with iron ore.

In the first locality Sub-Assistant B. B. Gupta notes that the vein is about 10 feet and in the second about 12 feet wide. Traces of silver were present in the ore from the first locality.

Limestone.

Yamethin district; Burma.

Limestone is quarried for building purposes from the hill 2 miles 85° E. of N. from Taungbotha in the Yamethin district of Burma. It is described by Sub-Assistant B. B. Gupta as a medium-grained greyish limestone sometimes interbanded with white, rather coarse-grained crystalline limestone. It contains nearly 15 per cent. of magnesium.

The Lower Bhander limestone in Bundi State, Rajputana, is the stone used by the Bundi Portland Cement Works. It gives an admirable cement and certain beds are well suited for lime. The Upper Bhander limestone, in Mr. Coulson's opinion, offers great possibilities for economic development.

Bundi State; Rajputana.

The limestones of Sirohi State, Rajputana have considerable economic importance. At present, those in the neighbourhood of Abu Road are being developed. Numerous lime kilns can be seen around Murthala (24° 31′ : 72° 51′) and the lime is railed to various localities. The stone is also used for building purposes and for railway ballast.

Sirohi State; Rajputana.

According to Mr. A. L. Coulson the quality of the limestones varies greatly and intrusive rocks have greatly deteriorated their value. Where a product of commercial purity is needed, impurities such as biotite, quartz, etc., would probably prevent their application for the manufacture of cement.

Mica.

Mr. Coulson records a pegmatite containing muscovite of fair size, but too small and of too poor quality to be worked, 2 miles east of Sahela (24° 47′ : 73° 8′) in Sirohi State, Rajputana.

Sirohi State; Rajputana.

Petroleum.

With regard to the prospects of obtaining oil in the parts of Myingyan and Meiktila visited by Mr. Barber, it is thought that any of the less broken anticlines in the Pegu series might prove productive, but on the whole the prospects are not good. In the absence of satisfactory palæontological evidence it was found impossible to refer these deposits to any exact horizon in the Pegu series, but they appear to be more estuarine in character than the productive rocks of Yenangyaung and other areas. The Lebya and Myinthadaung anticlines are much faulted, and therefore unlikely to prove productive, while many of the more favourable structures have been tested by various companies, so far without success.

Myingyan and Meiktila districts; Burma.

Pyrites.

Yamethin district; Burma.

In association with galena, iron pyrites in appreciable quantity was found by Sub-Assistant B. B. Gupta 3½ miles N. E. of Sedo and also at a place 2½ miles N.E. of Kyatpye in the Yamethin district.

North Arcot district; Madras.

In the Forest Reserve, about 2½ miles south of Tanniar bungalow in the Polur *taluk* of the North Arcot district, a thin band of dark-looking fine-grained rock was found by Mr. Vinayak Rao among banded quartzites of the Dharwar system. Charnockites are found to the east of this, and the older gneisses to the west. An analysis by Mr. V. S. Rajagopalan has yielded the following result:—

Moisture	3·40
SiO_2	19·35
Al_2O_3	1·66
Fe	21·77
Fe_2O_3	19·32
SO_3	5·30
S	25·16
MgO	·94
CaO	Trace
Mn & Ni	Traces
Undetermined	3·10
	100·0

Saltpetre.

Yamethin district; Burma.

The sandy soil from the foot of the hillock 3 furlongs west of Sagyin in the Yamethin district of Burma on being analysed was found to contain potassium nitrate. It is reported that it appears on the surface as an efflorescence in certain seasons of the year, but when Sub-Assistant B. B. Gupta visited the locality no efflorescence was met with. It is reported to have been extracted from the soil and used during the Burmese war for the manufacture of gunpowder. Our attention was drawn to it by the Subdivisional Officer of Yamethin, Mr. K. M. Yin, who sent Mr. Gupta a sample of soil from Yindaw (20° 43′; 93° 56½′) in the same district which also contained potassium nitrate

Silica Sand.

Bundi State Rajputana.

A mile south of Barodhia (25° 29′ : 75° 37′) in Bundi State Rajputana, a grit has been noted which crumbles to a sand on the application of very slight pressure and which might be utilized for the purposes of glass manufacture.

Sillimanite.

Bamra State; Bihar and Orissa.

During a mineral reconnaissance of Bamra State, Bihar and Orissa, by Mr. H. Cecil Jones and Dr. Krishnan, some bands of kyanite sillimanite schist were discovered and may prove of economic importance, but until large samples of the material have been tested practically it is not possible to obtain an idea of its value. From a microscopic examination of the material some of the bands appear to be fairly pure. These schists occur in two widely separated areas, both of which are at long distances from a railway; the latter fact may prove a serious objection to their being of economic value at the present time. One of these deposits was found by Mr. Jones near Palsama (21° 17′ : 84° 55′) and the other was found by Dr. Krishnan near Balram (Ballam) (21° 32′ : 84° 52′).

"Soap Sand."

Upper Burma.

Sapya or Sand Soap was observed in the Meiktila, Myingyan and Sagaing districts, occurring as an efflorescence over the softer sandstones of the whole area. It is collected locally for use as a soap, and is composed mainly of sodium hydroxide and calcium carbonate.

Steatite.

Yamethin district; Burma.

Steatite was found in small quantity in the limestone on the hill 2 miles E. of Taungbotha in the Yamethin district of Burma. It is supposed to have been derived from the magnesium carbonate, which the limestone contains. The quantity so far obtained is not promising from an economic point of view.

In the Jeoria village (25° 26′: 75° 5′) area, about one mile north of Kakralio (25° 24′: 75° 6′) good steatite is mined on a small scale. The country rock is a buff, dolomitic limestone dipping north at 80°. Just north of the mine there is a low hill of buff chert, probably derived from siliceous replacement of the limestone. The occurrence, according to Mr. Bradshaw, is more in the nature of a pocket than a vein, and occurs at the junction of the limestone with the chert. The pocket is about 50-60 feet broad. and has been worked, by an open cut, to a depth of about 40 feet. The overburden is negligible. The first grade material consists of a pure, pearly-white rock; the second grade is blotched with grey; the rest is dark and unsaleable. The output of the mine was from 50 to 60 *maunds* per diem. Of this 20 to 25 *maunds* are of first-grade and the rest second-grade material. The third-grade is not included in the daily output. Operations were discontinued during the monsoon of 1925.

Mewar State; Rajputana.

In view of the mode of occurrence, the body is not likely to be continuous for any distance; on the other hand, there is the possibility of the occurrence of steatite in any place where the ferruginous limestone is both dolomitic and siliceous. The steatite is of excellent quality, and has distinct economic possibilities. The mine is about 22 miles from Bhilwara Railway Station.

Tin.

Many tin mines are worked in the sheets of the Mergui district surveyed by Mr. Sethu Rama Rau, and are distributed in two areas, one on the mainland comprising the tin mines of Karathuri, Klong, Banhuni, Klong Yung, Klong Nam Noi, Pre Sai, Klong Lama, Klong Sai Den, Maliwun, etc., and the other in the islands fringing the coast, the most important mines of which are in the islands of Lumpi and Pulo Bada.

Mergui district; Burma.

On the mainland the tin ore is obtained from alluvial flats, the ore being derived from tourmaline-muscovite-cassiterite pegmatites, and cassiterite-bearing quartz veins closely associated with bosses of granite and pegmatite lenticles; in the islands it comes from cassiterite-iron-oxide-bearing quartz veins. Mr. Sethu Rama Rau is of

the opinion that the following areas might be advantageously prospected :—

(1) The whole belt of country from the source of Klong Nam Noi- Pre Sai in survey sheet 96 $\frac{J}{11}$ northwards to Kadin at the source of Kyaukpon Chaung in sheet 96 $\frac{J}{9}$.
(2) The alluvial flats north of Bankachon from mile 16 to mile 18 on the Victoria Point—Maliwun road.
(3) The country adjoining the Kayang area in Lumpi island.
(4) The north coast of Pulo Bada island.

Water (*see also* Engineering Questions).

Ranchi; Bihar and Orissa.

Mr. J. A. Dunn was asked to report on a new well site at Hinu 4 miles from Ranchi. The present pumping station and well are supplying water to the Hindu Clerk's Quarters belonging to the Secretariat. and to the Accountant General's Office. A considerable increase in the number of buildings in these quarters is proposed, and water will also probably be required for the adjacent Duranda Residential Staff quarters.

The present well on the south bank of the Bhusur (or Pundag) Nadi, just north of Hinu village, is inadequate even for present purposes during the dry season, and the consumption of water has to be restricted To increase the supply a channel or drain has been built from the side of the well diagonally across the stream bed on the granite bottom, so that the seepage in the stream-bed may be added to the well.

Some 200 yards to the west of the well and at a sharp bend in the stream, is a bar of granite-gneiss across the river. The river bed on the well side, or to the east of this bar, is about 8 feet below the bed of the stream on the upstream side, a considerable drop for this small stream. In the dry season, therefore, the water in the deep sand of the stream-bed above this bar is held up and there is very little seepage through the bar to the bed of the stream below. To the east of the well there are also a number of granite outcrops in the bed of the stream, so that in the dry season the well is really drawing water from the very short and narrow basin of sand in the stream below the bar. The result is that the supply of water in this well in the dry season amounts to little mor than

what is held in the sand of this short stretch of stream-course after the surface water runs dry, *plus* any additional water that may seep in from the surrounding fields. The depth of this sand ranges up to 8 feet.

On investigating the stream-bed immediately above the granite bar, Mr. Dunn found that at the sharp bend the stream had at one time cut quite deeply along the south bank, and that the bed here was filled with sand down to at least 8 feet, and saturated with water. A deep channel saturated with water could be traced upstream either in the centre of the stream-course or towards the south bank, but the deepest point was clearly at the bend immediately above the bar. The well should accordingly be sunk on the south bank at this point and a drain run out from the side of the well into the river, as has been done in the case of the present well. It will be possible to pump this well from the present pumping station by means of a pipe line.

Chalisgaon ; Bombay.

For many years attention has been given to the subject of the amelioration of the water shortage at Chalisgaon Railway Station, Great Indian Peninsula Railway. In spite of great efforts and a large expenditure of time and money, the supply of water for railway purposes still remains unreliable and insufficient, and at present water is being bought from the possessors of good wells a mile or so away from the station.

About five years ago, a dam was built across the Ar river just below the double loop near Warthan (or Wulta) seven miles south of Chalisgaon. Owing partly to lack of sufficient geological information at that time, the dam, although established on a solid rock-foundation in the stream-bed, failed to secure rock or even impervious material for the foundations of its abutments. Wing walls were, subsequently, carried 300 feet on each side into the banks. But even these failed to find rock at a level above the stream-bed. The material encountered was invariably conglomerate, gravel or open-textured débris, highly calcareous, irregularly bedded and exceedingly porous, and ranging from 20 to 40 feet in thickness.

As Dr. Fox, who has been in charge of these investigations, remarks, it is not surprising, therefore, that leakage takes place round the ends of the wing walls. Some of this seepage water finds its

way back to the Ar river below the dam—often in copious springs just below the dam. A far larger quantity of this infiltrating water simply disappears into the thick alluvial débris and, gravitating along its conglomeratic basal zone, eventually emerges far down the valley into the various streams which converge on Borkheda.

Water, as a gravity supply, is available from the Warthan reservoir, after a good monsoon, up to the end of March. From the middle of April to the next refilling of the reservoir, no water is passed down the pipe line. Recent measurements below the dam show that there has been a diminution in the leakage from around the wing walls of the dam back to the Ar river. Hopes are entertained that the silt carried into the alluvium by the infiltrating water is slowly sealing up the interstitial spaces and thus improving the water-tightness of the basin, but there are reasons for believing that leakage channels are enlarging in other directions. In spite of the good rainfall in 1924, the reservoir became so depleted by April 15th in 1925 that no water could be passed into the pipe-line. This is not the only evidence indicative of a marked deflection of the sub-soil drainage since the dam was built. Previous to the building of the dam there was a fair hot-weather stream-flow in the Ar (Dongri) river at Chalisgaon. This evidently represented sub-soil water under the bed of the stream which had been caused to emerge by the outcrop of rock across the river below Chalisgaon. The hot-weather flow must have then been sufficiently attractive to justify the expense incurred in building the head-works and cutting the canal which a few years ago irrigated the tract west of Patunda. Dr. Fox notes that since the dam and its wing walls were built, the sub-soil seepage has been deflected into the main mass of the Ar alluvium, and the stream-flow at the head-works of the Takli canal reduced to a mere trickle. As a result, the Takli-Patunda irrigation scheme has been overtaken by disaster, and the works have been allowed to fall into disrepair for lack of water in the hot months. It may take several years more for the alluvium to absorb all the water it can hold before the stream-flow at Chalisgaon regains its past volume. It is possible that, with the increased height of the ground water level in the alluvium at Warthan, the seepage water may emerge elsewhere and not back into the Ar valley. In the circumstances, Dr. Fox is disinclined to suggest further experiments at the Warthan dam for at least 10 years.

The alluvium discovered in founding the Warthan dam is now known to be extensive. It stretches northward to beyond Chalisgaon and spreads into the valleys of the Titur and Utvali. Its thickness does not appear to be more than 40 feet, but this dimension has not been tested at many places. It appears to be thickest on the watershed between the Titur and the Ar. It is almost entirely absent from the bed of the Titur and it is thin or wanting in the stream-course of the Ar. The basal layers, wherever uncovered, at the Warthan dam, at the confluence of the Ar with the Titur, etc., are usually a conglomerate composed of basalt nodules and rounded geodic fragments set in a calcareous matrix. Above this are irregularly bedded layers of gravelly *kankar* and calcareous gritty clays--all highly porous.

The Older Alluvium.

It is peculiar that this alluvium ends rather abruptly on a line parallel to and south of the course of the Titur. From the Titur northward amygdaloidal basalt and other types are exposed, and the ground rises steadily to the watershed on which the railroad runs north-eastward from Rohini through Chalisgaon to near Galna.

The occurrence of basalt close under the stream-bed at the Warthan dam and its appearance at the confluence of the Ar with the Titur suggests that the trap surface slopes northward. An exposure of bedded alluvium near the "6" of 1076 on the west bank of the Ar at Chalisgaon (see 1-inch Survey sheet No. 46, p. 3) shows a dip of 10° to the south-west. From occasional, though poor, exposures, Dr. Fox was led to believe that the traps also dip gently in this direction.

Two years ago, Rao Bahadur M. Vinayak Rao made a hurried geological examination of the country around Chalisgaon and located a well on the watershed between the Ar and the Titur rivers within a mile of their confluence. At present, water is being pumped from a private well, Narayan Bankat's well, in this vicinity. At about the same time, 1923, the services of a water diviner were obtained with a view to fixing a site for a railway well. Three sites were successively chosen. In No. 1, an existing well known as Ebrahim's well, on the high ground half way between Kotegaon and the Titur, 30 feet of alluvium had been proved. The well was deepened, still in alluvium, and an infiltration heading driven from the bottom. A pumping test showed the well to have a slow recovery. On No. 2, nearer to the Titur and close to the pipe line, a new well was dug to a depth of 33 feet entirely in alluvium; the recuperative test was

most unpromising. No. 3 site, still closer to the Titur and beyond the pipe line, was near the margin of the alluvium. A well sunk here encountered 16 feet of alluvium, and then struck Trap; it was carried down to a total depth of 48 feet, but the recuperative test was disappointing.

From the straightness of the Alluvium-Trap boundary along the south side of the Titur river, it is permissible to suspect a fault or at least a somewhat steep bank along which a buried stream-course may be conjectured. The greatest quantity of underground water would be tapped if this stream-course could be "hit" by a well or boring. The best line for getting this result would be along the line of the watershed between the Titur and Ar rivers which is the line suggested by Mr. Vinayak Rao.

In the circumstances, Dr. Fox considers it worth while putting down two or three bore-holes southward from No. 3 site to prove the depth of the alluvium and the outline of the rock surface. If the data indicate the presence of the supposed "bank" Dr. Fox recommends a heading to be driven for some distance from the bottom of No 3 well and a charge of dynamite exploded to open up the fissures. If no such bank or irregularity in the *infra*-alluvial rock surface be demonstrated, a deepening of No. 2 well is recommended.

Had there been no restrictions of any kind, Dr. Fox would have chosen a site exactly between Narayan Bankat's well and the confluence of the Titur and Ar rivers for the first bore-hole, and would then have put in a line of holes 30 feet apart on a south-east to north-west alignment towards each stream. From the section thus obtained the deepest place in the alluvium would be the best in this neighbourhood. Experiences at Bhusawal. Akola and other places are enough to explode any hope of artesian water from deep borings in the Trap in quantities which are likely to be attractive.

Manmad ; Bombay.

As a result of Dr. Fox's investigation and report in 1923, the Panjhan River (Gravity) Project was abandoned. Search further away from Manmad has since failed to discover a suitable site for a storage dam from above which the impounded water could be run as a gravity supply to Manmad

In consequence of the urgency for a satisfactory supply of water for engine purposes in Manmad, it has now been decided to re-

consider the question of obtaining water by pumping. A pumping scheme had, several years ago, been suggested in connection with the building of a dam on the Sakhi river. The site lies 11 miles east of Manmad, just half a mile south of mile 171 on the main line, and at an elevation of roughly 250 feet below that of Manmad. The distance and the "head" were unattractive factors. It was, however, estimated that a 60-foot dam, if built in the gorge immediately above the village of Mandwar, would secure a catchment of nearly 31 square miles, on which the rainfall would be about the same as that at Manmad -22 inches annual average.

Recent surveys and gaugings have shown that a 60-foot dam above Mandwar would enclose a reservoir basin having a storage capacity of over 1,400 million gallons. Allowing the top 5 feet depth for losses by evaporation and absorption—a volume equal to 350 million gallons—the available supply from the reservoir would, theoretically, be upwards of 1,050 million gallons. The estimated demand for Manmad is less than half a million gallons a day, giving a total of barely 150 million gallons a year, so that the water impounded would be equivalent to a several years supply for Manmad from a single filling of the reservoir.

In view of the possibility of such an abundance of water, and the fact, newly emerged, that the cost of pumping by modern plant is not unduly heavy, the Sakhi Scheme has much to be said in its favour. It is understood that water impounded at Mandwar would be utilized as a gravity supply for Nandgaon, six miles down the line. It is thus evident, that if the estimated quantity could be secured by the dam, a gravity project for an additional quarter million gallons a day, could be established for Nandgaon.

In addition to these considerations, it is hoped that, in the near future, the Railway Electrification Scheme, now being extended inland from Bombay, will be carried as far as Nandgaon. If this be done, and the Mandwar dam actually impound the calculated volume of water, it will not be necessary to water locomotives at Manmad. All engines requiring water could draw their supplies at Nandgaon. The present water-supply of Manmad would, perhaps with a little deepening of the existing reservoir there, be sufficient for the projected needs of Manmad under the remodelling scheme. The pumping plant at Mandwar could be dismantled as the whole of the reservoir water would be available as a very satis-

factory gravity supply for the then greatly increased requirements of Nandgaon.

From what has been conjectured it is evident that the Sakhi River scheme is worthy of a detailed examination from the meteorological and the geological aspects. For this purpose Dr. Fox was deputed to revisit the area and submit a further report.

The determination of the rainfall and its range of fluctuations, the estimation of evaporation losses, and the measurement of the run-off flow from the catchment, are being carried out by the engineers of the Great Indian Peninsula Railway.

The average annual rainfall for Manmad (period 1890-1919) was 22·12 inches so that the rainfall for 1924, *i.e.*, 23·57 inches is about the average. The erratic nature of the rainfall in this region is well known, heavy falls being precipitated in full view of places quite unaffected. This capriciousness may explain the lower rainfall on the Sakhi catchment which is usually not much more than 15 inches.

From the figures which were obtained in the stream gauging operations, the actual run-off discharge for the catchment is 192·120 ×6·25 =1,200·75 million gallons. This quantity, if it can be stored, would be ample for the needs of Manmad and Nandgaon, calculated at ½ and ¼ million gallons a day respectively, for 21 months (638 days). The supply for this period would be 480 million gallons leaving some 720 million gallons over to meet losses by evaporation etc. for two years. As it is improbable that the "Rains" would fail absolutely for two successive years the project seems assured from the meteorological aspect.

In the event of two or more successive years of normal or good rainfall the reservoir must overflow to discharge the surplus water. This flood or storm water is, it is understood, to be dealt with partly through a spill-way to the east of the dam, and partly by a cascade over the dam. The question of scour in the thick alluvium just below the dam is one of the questions to be considered in the geological aspects of the scheme.

Dr. Fox reports that throughout the area under consideration from Manmad to Rohini, there is generally only a thin covering of soil, except locally in stream-beds and banks. The ground slopes quickly from the Ajanta scarp and then flattens for a considerable distance from Mandwar. The underlying rock on the

catchment is bedded, soft, amygdaloidal and vesicular basalt. It is only on the higher grounds such as that on each side of the gorge at the site of the dam that fissured doleritic basalt is clearly seen.

The above considerations would lead to the conclusion that the rocks of the catchment are more or less impervious. However, these partially decomposed traps absorb water and heat so that evaporation losses from the land surfaces must be large. As a result of these factors, light showers of rain, aggregating less than one inch in 24 hours, might be entirely lost by evaporation and absorption, except when the rate of precipitation is rapid.

In Dr. Fox's opinion the allowance of the top 5 feet depth of the full reservoir should be enough to meet the evaporation and absorption losses from the water-spread, *i.e.*, when the reservoir is filled. The water-tightness of the basin, so far as can be seen, appears to be good, but in so important a scheme caution is desirable and the basin should be tested with trial pits.

It is imperative that the trench on the line of the dam should be taken down to solid rock so that the dam may have this material for its foundation throughout. Dr. Fox thinks that rock will be met with at shallow depths in the sides of the gorge. Clay may possibly be found in digging the foundations of the dam, and the temptation to remove it for use in the dam may arise. The temptation to remove this clay need not arise if the dam is built wholly of masonry. An earth-dam with a masonry core wall is seldom as water-tight as an earth-dam with a puddled clay core wall. The last type is impracticable because to obtain suitable clay the country side for a radius of 10 miles would have to be painstakingly scraped of its black cotton soil and dark red clay.

As regards the flood discharge, even with a masonry dam, there will be heavy scouring in the deep, soft alluvium below the dam if a big flood is passed. The saddle and lateral valley to the east are suggested as natural features suitable for a spill-way for all flood and storm water from the reservoir.

Owing to the short steep slopes on the scarp of the Ajanta Hills to the south and the low gradient of the stream-beds after they leave the hills, most of the silt will probably be deposited above the actual reservoir basin and silting will be trifling in the reservoir itself.

As regards the safety of the dam from displacements due to fault-movements or earth tremors there seems little to fear.

Careful scrutiny in the vicinity of the dam site failed to discover any evidence of faulting which might affect the water tightness of the reservoir.

If reasonable care is exercised in building the dam, the scheme should prove successful as regards efficiency of storage. According to Dr. Fox it would be difficult to find an equally attractive site anywhere else in this region, except perhaps one for a bigger scheme on the Maniad River south-west of Pimparkhed Station.

Ahmedabad and Kathiawar; Bombay.

During November and December 1924, Mr. W. D. West visited the Ahmedabad district and Kathiawar, in the Bombay Presidency, in order to examine the cores obtained from four borings put down for purposes of water-supply. They were situated as follows: (1) Dhandhuka, in the Ahmedabad district; (2) Botad, in Bhavnagar State; (3) Jamnagar, in Nawanagar State; and (4) Satapur Bridge, near Dhrangadhra, Dhrangadhra State. Of these the Dhandhuka hole had passed through 292 feet of alluvium and 921 feet of Deccan Trap lavas, making a total of 1,213 feet from the surface: the Botad boring had pierced 501 feet of Deccan Trap lavas: the Jamnagar boring 781 feet of Deccan Trap lavas and the boring at Satapur Bridge 538 feet of Upper Gondwana sandstones with some carbonaceous beds, followed by 7 feet of dolerite, presumed to be a sill. Details of the rocks examined will be reserved until the completion of these borings: but it may be mentioned that the Deccan Trap lavas are all of basaltic composition, those from Dhandhuka and Jamnagar being mainly of ordinary types, whilst those of Botad are of an unusual type, being rich in fresh phenocrysts of olivine and augite, usually to the exclusion of phenocrysts of felspar. Some plant remains were collected from the carbonaceous beds of Satapur Bridge.

Upper Burma.

As in all cases on rocks of the Pegu and Irrawadian series the water-supply question in the Meiktila, Myingyan and Pakokku districts of Burma, presents insuperable difficulties. No satisfactory scheme is possible for providing a really adequate water-supply from tube wells owing to the underground water being charged with magnesium and sodium salts. Where the alluvium is thick, and the thickness can only be surmised at best, shallow tube wells may give a fairly good

supply but the location of such wells can only be arrived at by a process of trial and error. In the jungle, sweet and potable water can generally be obtained from wells sunk in the alluvium of river valleys or from wells sunk at the lower end of a stretch of paddy fields. This the local inhabitants are generally aware of and in all the cases in which the villagers called Mr. Clegg to their aid, he found that they had previously tried all the likely locations which he pointed out to them. Deep borings are useless as the water of both the Pegus and Passage Beds, and also of the Irrawadian is frequently saline and sulphatic. On the more shaly Pegu rocks open tanks sometimes provide the village supply, wells being sunk where possible in the low ground below the outlet end, the *band* then acting as a filter, but as this is only run-off water, it cannot naturally be relied on to any great extent.

The same conditions as the above apply to the whole of the dry zone of Upper Burma, and the only aid the geologist can give is to point out areas covered by alluvium and enjoin the local inhabitants to make shift as best they can by a process of trial and error, the relatively lowest ground being first essayed.

Yamethin, Burma.

Mr. B. B. Gupta suggests two alternative schemes for the water-supply of Yamethin town: (1) the sinking of wells at Kadaung, a village some 2½ miles S. of the Railway station, and (2) the utilisation of the water of the fall 2½ miles N. E. of Yeu. In both cases the water would have to be carried to Yamethin by pipe-line. Deep tube wells are not likely to be successful in the town of Yamethin where the Irrawadian formation is suspected to be present at no great depth.

Pench Valley; Central Provinces.

In the Pench valley in the Central Provinces the village water-supplies are obtained from the main rivers which drain the area. Many of the villages are situated along the banks of the Pench and its main tributaries the Sukri and the Ghatamali Rivers, and during the dry weather water can be taken from the pools which occur at intervals in these streams. Mr. Gee observed that these pools vary with the strata, being found more regularly where the Motur clays outcrop, and again more noticeably on the upstream side of trap-dyke intrusions, several of which occur in the north eastern part of this area. The supply of villages not situated

near these rivers, or their tributaries is, however, drawn from wells. These are usually of no great depth, and as a result of the alternating character of the sandstone and clay beds a good supply of water is usually maintained. The beds, in general, dip to the north, so that any well sunk on the south side of one of the trap dykes yields a plentiful supply. Most of the sandstones of the area are apparently porous to a fair degree.

The area appears to have been affected by a number of faults, causing the repetition of the outcrops of the clays of the Motur series and these porous sandstones. This has apparently resulted in the prevention of the continued seepage of the underground water in the sandstone bands, the faulted clays sealing it off on the southern side of these clay outcrops so that wells sunk in the sandstones along these tracts should yield a good supply at a shallow depth.

In the area around the Tawa River of the Shahpur coalfield, and eastwards to the Chhindwara-Betul boundary, many of the villages depend on their water-supply from the Tawa River and its larger tributaries. The Tawa, during the early part of the year, before the rains, consists of a number of pools at intervals linked up by a mere stream meandering in the wide sandy bed of the river. Good water can be obtained from diggings sunk in this sandy river alluvium. Large pools occur throughout the year where trap-dykes crop out, and at other places where a hard bed of sandstone crops out across the river. For instance several lines of induration and silicification of the sandstones occur, following a general east-to-west strike, and deep pools are usually located in their vicinity. This is so in the Barakar and higher Gondwana beds. In the southern part of the Shahpur area the streams flowing over the Talchirs are fairly constant on account of the impermeability of the clays. But some of these clays, those of the Middle Talchirs, cropping out around Ratamati and south of the Sonada ridge appear to be very porous and a deficiency of surface water is noted in the hot weather. The water is then usually obtained from wells sunk in the Talchir clays, and when a more impervious band is met with a good supply is often maintained. This is similarly evidenced in the Talchir area around Khapa and Bhata in the eastern portion of the area.

To the north of the Sonada ridge, the red and green Motur clays being intercalated in the porous sandstones, those villages which do not obtain their supply from the Suk Tawa and its tributaries are kept well supplied with good water from wells. This was

especially noted at Bandabira near Sonada where a well on the lower ground between the village and the Suk Tawa River, was, during the month of March, full of water to within 3 feet of the surface.

Khyber Railway; N.-W. Frontier.

In connection with the water-supply of the Khyber, Dr. Fox is confident that water should be encountered near Landi Khana. There is some doubt about the porosity or otherwise of the shales and limestones, but he recommends the sinking of a well at the confluence of the stream courses east of Landi Kotal. If this stream-well fails to produce a large supply of water at a shallow depth, it will mean that the limestones are water-bearing, in which case a deep boring put down to these limestones should prove successful.

GEOLOGICAL SURVEYS.

Bihar and Orissa.

During the field season 1924-25, the Bihar and Orissa party consisted of Mr. H. Cecil Jones, in charge, Mr. J. A. Dunn, Dr. M. S. Krishnan and Sub-Assistant L. A. Narayana Iyer.

Bamra State; Bihar and Orissa.

Mr. Jones, whom Dr. Krishnan accompanied for training, carried out a mineral investigation of the Bamra State, during the course of which a preliminary geological survey was made. The rocks occurring in the State are mainly gneisses, schists and quartzites of Archæan age. In the north of the State typical micaceous and hornblendic Dharwar schists together with quartzites occur. Thin veins of pegmatite and quartz run through the gneiss and Dharwar rocks, but the quartz veins are usually barren and the pegmatite consists of quartz and felspar with black tourmaline or muscovite mica. The tourmaline and mica are usually small in amount, and the latter is not of much economic importance.

In the eastern part of the State are nearly horizontal massive well-bedded quartzites with interbedded trap flows; these appear to be of Cuddapah age. In the extreme south-west and south-east corners of the State are Gondwana rocks. These consist mainly of Talchir sandstones and shales and of Mahadeva conglomerates. None of the Gondwana coal-bearing beds were seen, and there seems little hope of finding coal in the State.

Singhbhum district; Bihar and Orissa.

Mr. J. A. Dunn continued his work in the Singhbhum district on Survey Sheets 73 $\frac{F}{10}$, $\frac{F}{6}$, $\frac{F}{5}$, $\frac{F}{2}$ and $\frac{F}{1}$ completing his survey in this part of the district. The greater number of the rocks are again regional metamorphics, but quite a large area of unmetamorphosed representatives of the Iron Ore series was covered. The Chakradharpur granite-gneiss is again an important type. A relatively small granite mass in the Girga Reserved Forest was met with, and the boundary of the Chota Nagpur granite-gneiss also touched upon. The most important outcome of the season's work has been the demonstration that the Dalma Volcanic series with the associated phyllites and mica schists of north Singhbhum belong to the Iron Ore series. The gradual metamorphism of the unaltered Iron Ore series types in the Kolhan, as they are followed west, both along the strike and across the dip, is, according to Mr. Dunn, remarkably clear. The zone of thrust-faulting between the metamorphics of north Singhbhum and the unaltered Iron Ore series, noted the two previous years, gives place to acute folding as it is followed to the west, on the western side of the Chakradharpur granite-gneiss. It is the presence of this thrust zone which seems to have been responsible for the correlation of the metamorphics to the north with the Older Metamorphics underlying the Iron Ore series in south Singhbhum.

The Iron Ore series may be divided into two lithological types, a sedimentary and fragmental on the one hand, and an igneous type of volcanic origin on the other. The sedimentary type varies from unaltered shales with occasional sandstones to highly metamorphic rocks, such as mica schists containing minerals like garnet, cordierite, staurolite, kyanite, sillimanite and piedmontite. All stages in this metamorphism may be noted both along the strike and across the dip. Volcanic tuffs are frequently found associated with the sedimentary types, and there is no doubt that many of the shales and phyllites consist in reality of fine volcanic dust.

For the most part, the volcanic flows appear to occur at the top of the Iron Ore series, but in several places there are interbedded phyllites of sedimentary or fragmental origin. At least no Iron Ore rocks of sedimentary origin have been found to overlie the thick series of volcanic flows. It seems possible that whereas in south Singhbhum the period was one almost purely of continual sedi-

mentation, in north Singhbhum the latter part of the period was one of pronounced vulcanism.

The general strike of the whole series is approximately east and west, with acute overfolding from the north, but successive, west-pitching, geo-isoclinal folds have brought the western extension of the outcrops of the Dalma Volcanic flows to a progressively more southern position. In the north-west portion of the area folding has been extremely acute, although remarkably regular, and this, combined wit the fact that the flows commence to be separated by intercalated phyllites as they reached their limit, has made the mapping exceedingly complicated. It is in this portion of the area also that the metamorphism becomes more severe.

In the Singhbhum district Mr. Dunn finds at least three distinct periods of basic igneous activity, all probably within Archæan times, the hornblende schists of the Older Metamorphic series being the earliest known and the Dalma Volcanics being the second in order of age. The Newer Dolerites, so abundant as dykes in the Singhbhum granite, may possibly be Cuddapah in age, although there is good evidence for assigning them also to the Archæan.

The succession in Singhbhum put forward by Mr. Dunn is as follows:

5. Newer Dolerite (altering to epidiorite)	Cuddapah or earlier.	
4. Granites.		
3. Ultrabasic igneous rocks.		
2. Iron Ore series with the Dalma Volcanic flows at the top.	Dharwar.	Archæan.
1. Older Metamorphics.		

Sub-Assistant L. A. Narayana Iyer worked under Mr. J. A. Dunn in S. E. Singhbhum and in the Porahat Government Estate.

Burma.

During the 1924-25 field season the Burma Party of the Geological Survey of India consisted of Mr. E. L. G. Clegg, (in charge) Rao Bahadur Sethu Rama Rau, the late Captain F. W. Walker, Mr. C. T. Barber and Sub-Assistant B. B. Gupta. With the exception of Rao Bahadur Sethu Rama Rau who continued the geological survey of the Mergui

district, the whole party was engaged in work on the Tertiary rocks of Upper Burma.

Mr. E. L. G. Clegg working in the Meiktila, Myingyan and Sagaing districts on the north side of the Thazi-Myingyan line, in an area bounded on the north and west by the Irrawaddy River and on the south and east by latitude 21° and longitude 96° respectively, completed parts of sheets 84 $\frac{O}{8}$, $\frac{O}{9}$, $\frac{O}{10}$, $\frac{O}{11}$, $\frac{O}{12}$ $\frac{O}{13}$, $\frac{O}{14}$, $\frac{O}{15}$, and $\frac{O}{16}$.

Sheets 84 $\frac{O}{10}$ and $\frac{O}{14}$ in the centre of the area had been previously surveyed in the 1912-13 field season by Mr. Datta who had divided the rocks into Irrawadian and Pegus, classifying the Pegus as belonging to the old Yenangyaungian sub-division, Dr. Cotter, to the south, classed the whole series as upper Pegus owing to the lack of any definite boundary, although he recognised the Irrawadian characteristics of the uppermost rocks.

Continuing northwards Mr. Clegg has mapped three divisions :—

Irrawadian.
Passage Beds.
Pegus.

No distinct boundaries occur between these three series which are generally conformable, but the Irrawadian is very arenaceous and usually consists of fawn-coloured false-bedded sandstones which contain an abundance of fossil wood; shales occur only locally as lenticles, whilst grits with quartz pebbles up to half-an-inch in diameter are occasionally met. One or two small areas which Mr. Clegg was at first tempted to map as old alluvium differ from the above in consisting of *kankar*-impregnated, arenaceous and laminated clays. In the latter in an area mapped by Mr. Gupta about 4 miles west of Yamethin, the pronounced dip which occurs, makes one more inclined to class them as a late phase of the Irrawadian.

The Pegu rocks consist of an alternating series of sandstones and shales in which the former predominate. The included sandstones are harder and more compact, contain thin calcareous bands and are less falsely bedded than those of the Irrawadian, whilst in isolated localities marine fossils specifically unidentifiable were collected from them. The shales of the series vary greatly in both colour and texture, ranging from fawn to steel-grey in colour and from fine aluminous to coarse arenaceous clays in composition and texture. Selenite is occasionally found in them in small quantity.

The Passage Bed series was introduced after consultation with the other members of the party to distinguish rocks which, owing to the rarity of exposures, the lack of fossils and the lithological similarity of the rocks in the exposures seen to both Irrawadian and Pegu types, could not be satisfactorily classified. Some such division as this seems inevitable at any rate as a temporary scheme —if the rocks are to be divided at all. In the type areas of these rocks in the Irrawaddy river valley south of Singu, the division between Pegu and Irrawadian is represented by either a red earth bed or a ferruginous conglomerate, indicative of an unconformity, that is a temporary halt in the process of sedimentation, whilst in the area mapped by Mr. Clegg, no such red bed is present. Although possessing occasional local unconformity, the beds shew a general change from marine to fresh-water conditions.

The rocks are folded into a series of broken anticlines and synclines arranged "*en échelon*" on a strike which varies from N.W.—S.E. in the south of the area to due N.—S. in the north. The crests of the anticlines form the intermittent hill ranges and are seen as isolated peaks and "hogsbacks," Taungtha Hill being the highest and most characteristic, although other hills approximating to it are found running N. by W. from Natogyi, and from east of the village of Myotha south towards Meiktila. In the east of the area mapped low hills run N.—S. along longitude 96° and, south of Ava at the north end of this low hill range, much broken and contorted hard Pegu sandstones crop out and are unconformably overlain by Irrawadian gravels and sands. These Pegu sandstones were placed in the Sitsayan division of the Pegus by Mr. Datta but no palæontological evidence has been obtained to substantiate the subdivision.

The distribution of the rocks follows the topography, broken anticlines of Pegu rocks forming the hill ranges and Irrawadian the intervening valleys. The curious manner in which the Pegu rocks of the middle part of the eastern flank of the Taungtha Hill range and the western flank of Mingontaung have been scoured away, points to river action and was probably accomplished by the Irrawaddy River whilst in the process of changing its course from the Samon Sittang valley to its present site. It is similar to the scouring which can be seen being carried out at present by the Irrawaddy River on the eastern flank of the north end of the Pyalo anticline below Thayetmyo.

The late Captain F. W. Walker carried out geological survey work in sheets 94 $\frac{A}{1}$, 85 $\frac{M}{9}$ and $\frac{M}{13}$ and in parts of 85 $\frac{M}{10}$ and 84 $\frac{P}{12}$ in the Yaméthin, Thayetmyo and Magwe districts in continuation of his previous field season's work. The area surveyed, with the exception of sheet 84 $\frac{P}{12}$, includes the country between latitudes 19° 45′ and 20° and longitudes 96° 15′ and 95° 30′. Captain Walker recognised and mapped the following series:

4 Alluvium

3 Irrawadian.

2 Pegu series.

1 Archæan.

Archæan rocks occur east of Kyidaunggon in sheet 94 $\frac{A}{1}$ as a foothill spur from the Shan Plateau and consist of biotite gneiss traversed by a band of crystalline limestone striking N. N. W. They can probably be correlated with the gneisses with included limestones of the Sagaing Hills.

Pegu Rocks folded into small pitching anticlines and synclines, which can only be traced along the strike for short distances, are found in sheets 85 $\frac{M}{13}$, 85 $\frac{M}{6}$, 85 $\frac{M}{9}$. 84 $\frac{P}{12}$, 84 $\frac{M}{9}$ and 84 $\frac{M}{10}$ and form the back-bone of the Pegu Yoma in the centre of the area examined. In sheet 85 $\frac{M}{13}$ they occur as an alternating series of fawn-coloured sandstones and bluish thinly laminated shales; in sheet 85 $\frac{M}{6}$ as a series consisting of thin bands of calcareous gravel conglomerates interbedded in shales containing a small proportion of intercalated sandstones; in sheet 85 $\frac{M}{9}$ as typical Pegus, composed of alternates of shales and sandstones with calcareous bands, whilst in the main mass of the Yoma they are well exposed in the westward-flowing streams in sheets 84 $\frac{P}{12}$, 85 $\frac{M}{9}$ and 85 $\frac{M}{10}$ as a series of soft fawn-coloured sandstones and greyish blue shales which alternate in all proportions. Thin bands of calcareous sandstone are intercalated throughout the series and in these in isolated localities marine fossils were collected. A major syncline in this area was traced through successive sections for about 10 miles.

Irrawadian rocks occupy almost the whole of sheet 84 $\frac{A}{1}$ one th east of the Yoma and consist of a monotonous sequence of soft fawn-coloured sandstones, usually thinly bedded and well jointed. Extensive denudation of conglomeratic beds in the series, which can be well seen in the Thinwondaung and Peinyangtang Chaungs, has

given rise to gravel and pebble beds at Pyinmana. On the west side of the Pegu Yoma in the south-west of sheets 85 $\frac{M}{9}$ and 85 $\frac{M}{13}$ Irrawadian rocks occur in country having a very low contour and in which outcrops are extremely rare. In the north sheet 85 $\frac{M}{9}$—the Pegu-Irrawadian boundary is marked by a sharp change in the surface topography and the presence in some localities of a band of characteristic ferruginous conglomerate, about 18 inches thick and consisting of ferruginous concretions, gravel and, locally fossil wood, the whole being set in a ferruginous cement.

Alluvium covers the eastern portion of sheet 94 $\frac{A}{1}$ and occurs in small patches along the larger streams, whilst on the west of the Yoma is the large alluvial Taungdwingyi plain. Great difficulty was experienced in the whole area in separating alluvium from Irrawadian rocks and on the east of the Pegu Yoma in fixing the Pegu-Irrawadian boundary.

Mr. C. T. Barber in continuation of his previous season's work carried on the geological survey of the Meiktila, Myingyan and Pakokku districts, completing sheets 84 $\frac{P}{9}$, $\frac{O}{3}$, $\frac{O}{4}$, $\frac{O}{7}$, $\frac{O}{8}$ and those portions of sheets 84 $\frac{O}{12}$ and $\frac{O}{6}$ which lie west of the Thazi-Myingyan branch-line of the Burma Railways, and the Irrawaddy River respectively. In conformity with Mr. Clegg who was working to the east of Mr. Barber's area, and with whom the examination of the boundary between their two areas was carried out, the following rocks were mapped:—

Alluvium,
Irrawadian,
"Passage Beds,"
Pegu series;

whilst further to the south-west the following surface deposits were also recognised:—

Plateau Red Earth.
Plateau Gravel.

The following are the characteristics of the various series recognised:—

Alluvium.—Consisting of buff to brown sandy clay, composed of the re-sorted sands and clays of the Irrawadian, Passage Beds and Upper Pegus and containing abundant

kankar and fresh-water gastropods, with a little derived fossil-wood.

Plateau Red Earth.—Consisting of brick red, sandy clays in which *kankar* and derived fossil-wood are locally abundant.

Plateau Gravel.—Consisting of large quartz pebbles and abundant fragments of fossil-wood in a loose, coarse, sandy matrix. No boundary was delineated between the Plateau Red Earth or the Plateau Gravel and the underlying formations but the general distribution of the two former was noted.

Irrawadian. Consisting of bright, white, false-bedded sands and containing large blocks and trunks of fossil-wood and small quartz pebbles.

Passage Beds. Consisting of alternating loose, white, false-bedded sands, locally characterised by small quartz pebbles and buff to grey sandy clays with occasional shales and impersistent compact sandstones. Lateral variation is very characteristic of these deposits.

Pegu Series. Consisting of alternating compact, lustre-mottled sandstones and grey to blue shales and clays, in which false-bedding and lateral variation are conspicuous. These deposits are for the most part barren, but poorly preserved lamellibranchs and gastropods are recorded from several localities.

The major portion of sheet 84 $\frac{P}{9}$ is occupied by Upper Pegus, but in a broad syncline between Awzachan (95° 33'; 20° 57') and Thabutkon (95° 37'; 20° 57') villages, the soft false-bedded sands of the Passage Beds are represented, and continue northwards into sheet 84 $\frac{O}{12}$, where they form a belt some five miles in width, flanked on either side by rocks of the Pegu series and enclosing a small area of Irrawadian in the neighbourhood of Yonzingyi village (95° 34'; 21° 13'). On the western flank of this area of Passage Beds, the Pegu rocks are composed for the most part of hard lustre-mottled sandstones which are sharply folded and faulted into a pronounced "diaper" structure, forming the Lebyo Hills. Similar sandstones alternating with blue to grey shales and gypsiferous clays continue westward into the southern portion of sheet 84 $\frac{O}{8}$, to the foot of Mount Popa, and a similar type of lithology can be traced north-

wards in the hills forming the anticlines of Taungalin (95° 26′; 21° 6′), Kyatti (95° 22′; 21° 7′), Myinthadaung (95° ·19′; 21° 4′), and Kabat (95° 3′; 21° 4′). These anticlines pitch out in a northerly direction and the Upper Pegus give place to rocks of the Passage Beds which also "V" down the broad valleys between the anticlines themselves. Near Welaung (95° 7′; 21° 9′) is a small area of Irrawadian, which continues northwards to Kyaukpon (95° 7′; 21° 11′), where it is overlain by the extensive alluvium of the Sindewa Chaung.

West of the Kabat anticline the soft white sands of the Irrawadian again come in, and are here separated from the Upper Pegus and Passage Beds by a well defined red bed, which can be traced continuously in a north-north-westerly direction from Sainggaung village (95° 16′; 21° 4′), for a distance of twelve miles and intermittently for another ten miles to Lettok (95° 8′; 21° 17′), where it is finally lost beneath the Irrawaddy Alluvium. Irrawadian deposits occupy the greater portion of sheet $84\frac{O}{4}$, but rocks of the Pegu series again crop out in the Taungzin Hills in the extreme south-west. The boundary between the Irrawadian and the Pegus in this vicinity is obscured by the alluvium of the Saikgwa Chaung.

The whole of sheet $84\frac{O}{6}$ west of the Irrawaddy River is occupied by alluvium which extends into sheet $84\frac{O}{7}$, where it forms a belt some three miles in width on the right bank of the river.

Near Kuyuwa (95° 11′; 21° 25′) Pegus rise abruptly from the alluvium and in the cliff-like sections which occur here, the rocks are well exposed, but once the cliffs have been ascended the solid geology is obscured by Plateau Red Earth and good exposures in the Pegus are rare till the Kyauktat Hills are reached. These hills form the eastern flank of a faulted anticline, the rocks forming the western flank of which are extremely ferruginous and are overlain by the bright white kaolin bed which here characterises the base of the Irrawadian. The whole of sheet $84\frac{O}{8}$, west of the Kyauktat anticline is occupied by Irrawadian and alluvium, but exposures in the former are extremely rare on account of the surface deposits of Plateau Gravel and Plateau Red Earth, which here attain a considerable development.

Mr. S. Sethu Rama Rau, working in sheets $96\frac{J}{1}$, $\frac{J}{2}$, $\frac{J}{3}$, $\frac{J}{5}$, $\frac{J}{6}$, $\frac{J}{7}$ $\frac{J}{8}$, $\frac{J}{9}$, $\frac{J}{10}$, $\frac{J}{11}$, $\frac{J}{12}$ $\frac{J}{14}$ $\frac{K}{5}$ and $\frac{K}{9}$, completed the geological survey of the accessible Parts of the Mergui district. During the

course of his survey Mr. Sethu Rama Rau recognised the following series and lithological types:—

Moulmein limestones,
Mergui series,
Quartz Porphyry,
Gneiss;

whilst in Mergui and the adjoining islands, grits, sandstones (with occasional siliceous infiltrations in their cracks and joints), and conglomerates were seen over a wide area, unconformably overlying argillites of the Mergui series.

Gneisses are exposed near Talobusa village and the series is made up of alternating bands gently folded into an undulating ridge. They include all types from acid to basic, the former consisting of quartz with a little biotite and the latter of hornblende, biotite and pyrites with a little quartz. Their relationships with the Mergui series were not seen but Mr. Rau believes them to be older than the latter and probably comparable with the early granites and gneisses of the Mogok frontier region. Intruded into these gneisses are coarse, irregular granites and pegmatites whilst quartz veins of a later date intersect the whole. The general strike of the intruded granite and quartz veins is 12° W. of N. to 12° E. of S.

Regular ridges of quartz porphyry which are well exposed in the islands north of Pase Mira on the Talebusa Chaung, and in the island near Sungei Mukang adjoin the biotite granites of the gneissic series: the quartz porphyries and these biotite granites are believed to be genetically related.

The Mergui series is made up of slates, quartzites, grits, conglomerates, argillites and kaolinised sandstones and generally strike in a direction 70° W. of N. to 70° E. of S. They are folded into a series of anticlines and synclines and in Lumpi island complete reversals of the strata were seen within a distance of one hundred feet. North of Kayang on the east of Lumpi island a band of slate includes pebbles of granite varying in diameter from one to nine inches.

The Moulmein limestones, which consist of coarse crystalline unfossiliferous limestone, form the Turret islands, a group whose precipitous limestone cliffs rise sheer from the sea, thus rendering the relationships of the limestones with the rocks of the surrounding islands indeterminable.

Sub-Assistant B. B. Gupta, working in the Yamethin and Magwe districts, completed sheets 93 $\frac{D}{8}$, 84 $\frac{P}{16}$ and portions of sheets 93 $\frac{D}{7}$ and 93 $\frac{D}{8}$.

Sheets 93 $\frac{D}{8}$ and 84 $\frac{P}{16}$ consist of Upper Tertiaries and rocks of the Irrawadian and Pegu series were mapped. Lithologically the Irrawadian rocks are composed of soft loose sandstones and gravels whilst Red Earth is seen as a surface deposit in areas where the topography is flat. Fossil wood in quantity was only seen in two localities, the first 2¾ mile S.S.W. of Inbingyi and the second about 1 mile S.S.E. of Chinbyitkyin. In the Yedoyo Chaung a rather different type of deposit was met with, consisting of unfossiliferous argillaceous grey sandstones with occasional shale partings, but was overlain to the east by the usual type of gritty Irrawadian sandstone. Vertebrate fossils were scarce but a tooth, provisionally referred to *Cervus latidens* (Lyddeker), was obtained from the left Bank of Ingon Chaung, 2 miles N.W. of Indawgyi, and broken fossil bones from 1 mile S.W. of Indawgyi, and on the hill 3½ miles S.W. of Myohla. A *Mastodon* tooth, said to have been collected in Ingon Chaung, was seen in the possession of the Thegyan *hpoongyi*. Pegu rocks underlie those of the Irrawadian to the west and consist of alternating beds of sandstones and shales varying greatly in texture. They are folded into a series of anticlines and synclines, Irrawadian rocks occurring as outliers in two of the synclines; the more westerly of the latter is continuous with one mapped by Mr. C. T. Barber in sheet 84 $\frac{P}{11}$ during the 1923-24 field season. The axes of these folds approximate to the strike of the rocks *i.e.*, N.N.W.—S.S.E.

Red Earth occurs on Pegu rocks in flat areas in the north of sheet 84 $\frac{P}{16}$, and small fragments of fossil wood are common near the western boundary of the more easterly of the Irrawadian outliers mentioned.

The following fossils were identified from the localities cited :—

(1) Half a furlong S. of Sigon (in hard compact sandstone)—

Balanus sp., *Balanus* (*Chirona*) *sublævis*. J. de C. Sow., *Ceratotrochus alcocki*, Noet., *Oxyrhina spallanzanii*, Bon., *Pecten ? kokenianus*, Noet., *Arca* sp.. *Ostræa* sp.

(2) 1½ miles S.W. of Aingdo (in compact greyish brown sandstone)—

Carcharias (Prionodon) gangeticus, M. & H., *Alopias vulpes*, Gmelin.

(3) Bwet Chaung about 1¾ miles S. of hill "1470", Kyaukgyi daung, just below the junction of two streams :-

Balanus sp., *Membranipora* sp., *Ostræa* sp.

(4) 1½ miles N.N.W. of Aingdo (in calcareous sandstone)-

Marginella sp., *Ringicula* cf. *hornesi*. Seg., *Ringicula* sp., *Cardita* sp., Fish teeth (indeterminable).

(5) 2 miles S.S.E. of Aingdo (in calcareous sandstone)--

Ceratotrochus sp.

(6) 1 mile 5 furlongs N. 10° W. of Pyazi :—

Cerithium sp.

In sheets 93 $\frac{D}{7}$ and 94 $\frac{D}{8}$ Mr. Gupta worked along the boundary between the Samon Sittang alluvium and the ancient rocks of the Shan Plateau and was able to recognise the following types: gneissose biotite granite, crystalline limestone (sometimes garnetiferous), slates and quartzite. Although sufficient work was not carried out to make the relations of all these lithological types clear, Mr. Gupta formed the opinion that the slates and quartzites belong to the Chaung-Magyi series, recognised in the Northern Shan States by LaTouche, and evidence of the intrusive nature of the gneissose granites into this series was seen on the Kyatpye-Kangyi footpath in sheet 93 $\frac{D}{8}$, where fragments of quartzite and slate had been caught up in the granite. Besides quartz and granite veins, quartz porphyries were also noted in the Chaung-Magyis but only the former carried the various ores of lead, copper, iron, graphite, etc., noted during the course of the survey.

Central Provinces Party.

The Central Provinces party comprised Dr. L. L. Fermor (in charge), Messrs. H. Crookshank and W. D. West, and Sub-Assistant D. S. Bhattacharji. Dr. Fermor continued his survey of the Sausar *tahsil*, Chhindwara district, and the adjoining portions of the Nagpur district. For a while Mr. Crookshank accompanied Dr. Fermor and he was then allotted work on the Pandhurna sheet to the west of the

Sausar sheet. On completion of this he joined Dr. Fox in northern Chhindwara, where he was engaged in work on the Gondwanas, as well as in adjoining parts of the Narsinghpur district. Mr. West was allotted the Deolapar sheet in the Nagpur district; his work there was interrupted by a visit to Kathiawar, and was terminated early in order to enable him to commence work in the Himalayas with Dr. Pilgrim. Sub-Assistant Bhattacharji continued his previous work in the Nagpur district.

Chhindwara and Nagpur districts.

During this season Dr. Fermor completed the examination of a small tract left unfinished in the Sapghota Reserved Forest, Nagpur district, and thereby completed the Sausar sheet ($55\frac{K}{14}$). The Sapghota forest is occupied almost entirely by the continuation of the Mogra synclinorium mentioned in the previous review, and with the Mogra area exceeds in intricacy of folding and variety of rocks any ground yet investigated in the Central Provinces. The succession of rocks in the Sapghota forest comprises the complete series of stratified Archæan rocks of the Sausar *tahsil* referred to in the previous General Report from calc-granulites at the base to hornblende-schists at the top, with the exception of the gonditic horizon, which is represented only doubtfully by a thin band of garnet-quartzite. The dolomitic stage is represented both by the normal serpentinous types, and by the scapolitic Mogra suite referred to last year. In addition there is a thin stratum of felspathic quartzite sometimes micaceous, found at an horizon intermediate between those of the dolomitic and calcitic marbles, and overlying the garnet-quartzite referred to above. Finally in the N.E. corner of the forest there is a completely new type, namely a garnet-anthophyllite-schist, with large spongy pink garnets up to two inches in diameter, and prisms of anthophyllite up to one inch in length. In places the garnets are absent. This rock occurs in considerable masses, but the folding is so complicated, accompanied doubtless by much overthrusting, that it is impossible to be quite certain of its exact stratigraphic position; whether, for instance, the anthophyllite schist is a special metamorphic phase of one of the rocks previously studied, or whether it represents an horizon not hitherto encountered. After considering all the available data Dr. Fermor is of the opinion that this rock represents an additional horizon immediately above the hornblende-schists, a view which was confirmed in Mr. Bhattacharji's ground near Chorbaoli on the Ramtek sheet, where a small

outcrop of the same garnet-anthophyllite-schist was found in well folded, but less intricate ground, and again probably overlying hornblende-schist. In the previous season, at a point near Tekari about 2 miles to the north of the Sapghota anthophyllite-schist, and in much less intensely folded ground, a band of magnetite-quartz-rock, also probably overlying hornblende-schist, had been found. No evidence has been found, however, to show the relationship to each other of the anthophyllite-schist and the magnetite-quartz-rock, and these two have been grouped provisionally together until further evidence is forthcoming.

In addition to the anthophyllite-schist the intensely folded north-east corner of the Sapghota forest shows other fresh types; these, instead of representing additional horizons in the stratified sequence, are probably special metamorphic phases of previously studied types. Particularly distinctive is a mono-mineralic green schist composed, according to Dr. Fermor, of an amphibole with the pleochroism and extinction angles of pargasite, but optically negative. It is not yet clear whether this schist is a derivative of the diopsidites, and thus belongs stratigraphically to the dolomitic stage. In addition there are tremolite-schists, and actinolite-schists, both belonging to the dolomite stage, and also normal hornblende schists. There are also many varieties of pyroxene rocks representing both the dolomitic and hornblende-schist stages; one interesting type being a diopsidite rich in clinochlore and spinel. Large garnets have been formed not only in the anthophyllite-schists, but also in intensely compressed biotite-gneisses rolled out into schists. Sillimanite has also been formed as a shear mineral. As the result of a change, presumably of somewhat later date, but not before folding movements ceased, the garnet-anthophyllite-schists have in one place been converted into spotted chlorite-schists, the spots representing the former garnets. As will be judged from the foregoing catalogue of types the intensity of stress in this corner of the forest has been very great.

Dr. Fermor proposes to call the whole succession the Sausar series and to allot to the various stages the names shown in the accompanying table. All the stages named are found on the sheet mapped, with the exception of the Ramtek quartzites, which, judging from Mr. Bhattacharji's mapping, must overlie the anthophyllite-schists (Sapghota stage). As will be recalled from previous reviews the various members of the Sausar series as thus defined are usually

separated one from another by acid biotite-gneisses, which have been treated as ortho-gneisses representing large-scale intrusions that have separated one from another the various members of the stratified sequence. Mr. West, as a result of his last season's work has suggested, however, that certain of these gneisses, in particular the sillimanite garnet-gneisses or schists and the fine-grained biotite-gneisses, may really be para-gneisses and schists.

Tabular Statement of the Sausar series.

Name of stage.	Type localities.	Chief rock types.
Ramtek (N)[1] . .	Ramtek Hills . .	Sericitic quartzites.
Sapghota (N) . .	Sapghota Reserved Forest. (N) Tekari . . .	Garnet anthophyllite-schists ; chlorite-schists. Magnetite-quartz-rock.
Sitapar (C)[1] . .	Sitapar, Sapghota Reserved Forest,	Hornblende-schists,[2] garnet-amphibolites, pyroxenites.
Bichua (C) . .	Bichua (C), Bichua (N), Khapa Padri Reserved Forest (C). Mogra (C—for Mogra type).	White dolomitic marbles, cipollinos, spinel-, chondrodite- and serpentine-marbles, diopsidites, diopside-quartzites, tremolite-actinolite-schists. Scapolite-granulites, scapolite-diopside-marbles.
Chorbaoli (N) . .	Chorbaoli . . . . Sapghota Reserved Forest.	Felspathic muscovite-quartz-schists. Microcline-quartzites.
Mansar (N) or Gondite stage.	Mansar, Ramdongri (N), Waghora (C).	Gondite series, manganese-ore bodies ; perhaps certain garnet-quartzites.
Lohangi (C) . .	Lohangi, Ghotni (C), Maharkund (N). Devi (C), Ghogara (N), Junawani (N).	Pink calcitic marbles, calciphyres. Black manganiferous marbles, piedmontite-marbles, and some manganese-ores.
Utekata (C) . .	Utekata, Ghoti (C), Pareghat Reserved Forest (C). Jirola (C—for Jirola type).	Calc-granulite. Hornblende-biotite-granulites.

[1] The letters C and N indicate the Chhindwara and Nagpur districts respectively.
[2] In addition there are probably hornblende-schists, etc., representing intrusives, probably of the same age.

If the garnet-sillimanite-gneisses prove to be para-gneisses then three additional stages will be needed in the section of the Sausar series between the Bichua stage (dolomitic marbles) and the Lohangi stage (calcitic marbles).

In the Sausar series as thus defined perhaps the most important horizon is that of the Gondite series and manganese-ore deposits (the Gondite or Mansar stage). The rocks comprised by the Gondite series are of a very unusual type and it seems unlikely, though it is of course not impossible, that there should be two such horizons in the Indian Archæan sequence. For this reason there are prospects of correlating by its aid the Archæan sequences of several parts of India. The late Mr. Burton's Sonawani series of the Balaghat district is evidently equivalent to a portion of the Sausar series. The Chilpi Ghat series, which because of the basal conglomerates of Chilpi Ghat itself Mr. Burton regarded as separated from his Sonawani series by an unconformity, may, however, prove equivalent to another portion of the Sausar series. The difficulty of correlating the Chilpi Ghat series with the Sausar series on the basis of the manganese-ore horizon is due to the absence of marbles from the former and to the presence of the great thickness of phyllites overlying the manganese-ore horizon, and of the conglomerates underlying the manganese-ore horizon; the phyllites are absent from the Sausar series as at present limited. Should subsequent work support Mr. West's suggestion, however, that the garnet-sillimanite-gneisses and schists are para-gneisses, that is to say metamorphosed argillaceous sediments, one of the difficulties will have disappeared, for it will be possible for them to represent the Chilpi phyllites in a more intensely metamorphosed form.

Gonditic rocks have been found in the Gangpur State of Orissa and sporadic occurrences are known in Central India, Bombay and possibly Rajputana (Banswara). The white marbles of Rajputana are so similar lithologically to those of the Bichua stage of the Sausar series that another line of correlation may lie here. It seems possible also that we may be able to correlate the rocks of the Eastern Ghats in the Madras Presidency with those of the Central Provinces, if Dr. Fermor is sound in his suggestion that the koduritic rocks of the Ganjam and Vizagapatam districts may be hybridised gonditic occurrences.

As is noticed on page 92 certain of the rocks of Sakrasanhalli in the Kolar district of Mysore bear a close resemblance, some to

members of the gondite series and others to the black manganiferous marbles of the Central Provinces (Lohangi stage). Mr. Jayaram of the Mysore Geological Department considers that the rocks of the Sakrasanhalli area represent an older section of the Dharwar series than has hitherto been recognised.

By using the Gondite series as a datum line, with the marbles as confirmatory evidence, it may prove ultimately possible to link up with the Central Provinces certain Archæan tracts of Rajputana, Singhbhum and Orissa, the Eastern Ghats of Madras, and Mysore.

Chhindwara district.

Before joining Dr. Fox in northern Chhindwara Mr. Crookshank spent about a month in the vicinity of Pipla and Mohgaon on the Pandhurna sheet (55 $\frac{K}{10}$) in order to complete the boundary between the alluvium and the Deccan Trap and to trace to the west various faults and dykes seen in the Sausar tract to the east. A marked east-to-west fault with a downthrow of some 60 feet to the south was traced through the traps at Pindrai and Sawajpani, and three basaltic dykes were mapped. The flows themselves are of the normal type, mainly basalts with some dolerites. In the vesicular surface of one of them Mr. Crookshank found abundance of the zeolite ptilolite. The surface relief round Pipla is marked and there are distinct textural differences between certain of the flows, as well as two marked intertrappean horizons. In one of the latter abundant remains of plant fossils were discovered, as well as shelly fragments. The plant fossils include two coniferous fructifications, which have been passed for purposes of study to Prof. Sahni of Lucknow, who considers them to be of some importance.

The flows of Pipla compared with those of Linga near Chhindwara appear to be identical. It was found that the basal flow of Pipla was markedly porphyritic like the basal flow of Linga, that the second flow appeared to be identical in each area, being doleritic with a flaggy section, and that the third flow of each area is markedly rich in chlorophæite, though with this difference that the Pipla flow is largely doleritic whereas the Linga flow is basaltic. Two other pairs of flows seem to be sufficiently similar to be correlatable. If the parallelism between these two sets of flows can be trusted, it affords an illustration of the fluidity of the Deccan Trap lavas. Pipla is 25 miles S.S.W. of Linga, so that the same flows must have spread continuously over a distance of more than 25 miles.

Nagpur district.

Mr. W. D. West commenced work this season on the Deolapar sheet (55$\frac{O}{8}$), which is two sheets to the east of the Sausar sheet mapped by Dr. Fermor and immediately north of the Ramtek sheet mapped by Sub-Assistant Bhattacharji. In the ground mapped cappings of Deccan Trap were absent, but amongst the Archæans, on which the work was much hampered by widespread alluvium, Mr. West found most of the main stages of the Sausar series as developed in the Sausar tract. The rocks are arranged in parallel belts striking across country to the S. E., that is with a similar strike to that of Sausar; the structure, however, is much simpler than in Sausar. First there is a synclinorium of dolomitic marbles and gneisses in the Junawani Reserved Forest: this is followed to the north-east by an anticlinorium of calc-granulites and calcitic marbles, between Piparia and Jhanjharia; this again by a synclinorium of dolomitic rocks (of Mogra facies) west of Dongartal, overturned towards the north; and this by some simple anticlinal and synclinal folds of calc-granulite and calcitic marble, between Dongartal and Kamti. All these folds are continued to the south-east where they mostly disappear beneath alluvium. Mr. West's work confirms Dr. Fermor's provisional order of superposition which places the calc-granulites at the base, and also confirms the inversion of the beds in the belt of country to the south as mapped by Messrs. Cotter, Clegg, and Bhattacharji.[1] The rock sequence in Mr. West's ground is as follows:—

Dolomitic marbles and associated rocks.
Spotted mica-schists.
Muscovite-quartzites.
Para-schists and gneisses (including composite gneisses).
Calcitic marbles.
Calc-granulites.

In addition there may be granite and hornblende-schist at all horizons.

The spotted biotite-schists are the rocks termed schistose sillimanite-biotite-gneisses by Dr. Fermor, whilst the para-schists and para-gneisses comprise Dr. Fermor's fine-grained biotite-gneisses and associated schists. Mr. West's suggestion that the rocks of these two horizons may be metamorphosed sediments is an important one which, if verified, will necessitate a re-adjustment in views provisionally held hitherto.

[1] Rec. G. S. I., vol. LIV, p. 47.

The main reasons for the view that these rocks are para-gneisses and schists are the facts that they occupy a definite stratigraphical position and that if they were ortho-gneisses and schists they should show cross-cutting relations to the definitely accepted members of the stratified sequence, which they do not. Mr. West explains the supposed marginal contact effects on the dolomites as representing a change in the composition of the original sediments where grading into a sediment of another type.

Concerning the calc-granulites Mr. West accepts the view that they are the product of the *lit-par-lit* intrusion of an acid magma into calcareous sediments: he suggests that they were not formed from a limestone as relatively pure as the overlying pink marble, but from a less pure limestone possessing a laminated or bedded structure which facilitated the introduction of the thin sheets of the acid magma that produced the hybrid. Concerning the nature of this magma there is room for a difference of opinion, as it has interacted so intimately with the limestone that its original nature can nowhere be seen within the calc-granulite. Also no feeders are seen. Dr. Fermor had postulated the fine-grained gneiss magma of group 1 as the intrusive, but if Mr. West proves correct in his views that this gneiss is a para-gneiss, then another source must be sought. If the fine-grained gneisses be excluded *in toto*, there is no competent igneous rock exposed. There is an abundance of leucocratic granite but its date of intrusion is subsequent to the folding of the banded calc-granulites. Dr. Fermor considers, however, that he has good evidence that a certain fine-grained gneiss containing grains of iron-ore (ilmenite in part) has been concerned in the formation of the calc-granulites. A possible solution to this divergence of views is that amongst the fine-grained gneisses are both ortho-gneisses and para-gneisses.

A notable feature amongst the rocks of the dolomitic suite is the mineral variety which is attributed to reactions between the dolomite itself and presumed original impurities. In particular the appearance at different points of forsterite, tremolite, and diopside is accounted for on the basis of the mass quantity of silica available. One interesting type discovered is a tremolite schist containing colourless garnet and yellow vesuvianite.

Another interesting point which Mr. West has worked out is the crystalloblastic order of the minerals. In ordinary igneous rocks the order of crystallisation of the minerals is deduced by noting

the relative idiomorphism of one mineral to another, and is dependent on the fact that the minerals have crystallised with falling temperature. In metamorphic rocks, however, the reactions by which the minerals are formed take place under the influence of rising temperature, so that in effect there is simultaneous crystallisation, giving a set of minerals representing the equilibrium under the highest temperature that prevailed. The shape of the crystals and their relations one to another will depend partly on such factors as crystallising force and partly on the particular reactions that take place. Instead of the " order of crystallisation " that pertains to igneous rocks we have the " crystalloblastic order " of Becke. In the area of high metamorphism we are considering, crystallisation must always have been complete, and it has, therefore, been possible by the study of a sufficiently large number of slides, to work out the crystalloblastic order of most of the minerals in these rocks. Leaving out certain minerals, the position of which is undetermined, the following order was arrived at :--

1. Sphene, sillimanite, tourmaline.
2. Epidote.
3. Muscovite, amphibole.
4. Biotite, pyroxene.
5. Scapolite.
6. Plagioclase felspar.
7. Quartz.
8. Potash felspar.

Nagpur district.

The area surveyed by Sub-Assistant D. Bhattacharji occupies the northern portion of standard sheets Nos. $55\frac{O}{7}$ and $55\frac{O}{8}$, between latitudes 21° 25′ and 21° 30′, beginning from the eastern margin of the Ramtek *tahsil* down to the Pench river on the west. The formations seen were alluvium and the Archæans, the latter comprising most of the members of the Sausar series as well as various gneisses and intrusive granites and pegmatites. The latter are divisible into two groups—older and younger—primarily by the amount of movement and metamorphism they have undergone and secondly upon mineralogical grounds. The rocks of the dolomitic suite have been found to separate the slabby quartzite and muscovite-quartz-schist noted previously. The former, seen typically in the Ramtek hills, is regarded as a typical sediment, whilst the latter, concerning the origin of which there may be some doubt, is well seen

in the Junawani Reserved Forest near Chorbaoli. Dr. Fermor considers Mr. Bhattacharji's evidence sufficiently good to justify the outcrops in these two areas being taken as typical of two different stages and has added them to his Sausar series as the Ramtek and Chorbaoli stages in the table given on page 78. The muscovite-quartz-schist of the Chorbaoli stage is described as a good mappable horizon and often contains pebbles distorted by crush, the presence of the latter being an additional criterion for its identification.

As the evidence obtained by Mr. West confirmed the order of superposition of the strata as worked out in the Sausar tract, the rocks of the Parseoni and Ramtek area must now be looked upon as a reversed sequence. Mr. Bhattacharji constructed an ingenious model with paper and plasticine representing the folds over a considerable strength of country in order to see how this inversion could be possible. It was found that with slight adjustments of the model it was possible to make pitching synclinal folds simulate anticlines and *vice versâ*.

Coalfields Party.

The coalfields party under the charge of Dr. C. S. Fox included Messrs. E. R. Gee and A. K. Banerji, and for a short time Mr. H. Crookshank. The field season was spent in a re-examination of some of the Central Provinces coal areas.

Central Provinces.

Dr. Fox and Mr. Gee are in agreement that the previous work in the Wardha Valley carried out by Mr. T. H. Hughes had fully elucidated both the structure and succession of the Gondwana strata in that region. The exploration which has taken place since Mr. Hughes mapped the Wardha Valley coalfields has allowed a little more precision to be obtained in regard to minor boundaries and faults in that area. Mr. Gee is of the opinion that the sandstones seen north of Ellichpur in the Amraoti district are newer than the Barakar beds—a view originally held by Mr. W. T. Blanford and also by Mr. J. G. Medlicott.

Dr. Fox and Mr. Gee have proved the existence of coal-bearing strata close to, and often exposed at, the surface to the north of the tract of Barakar beds shown on the older geological maps of the southern Satpura coalfields. This occurrence is due to the step-faulting which is present, and which has a down-throw generally to the south in beds which steadily dip northward.

Time did not permit of the separation of the coal-bearing formations from the younger strata in this region, throughout the area visited, a separation which the lack of exposures at critical points and the difficult nature of the country would have rendered laborious. Enough is now known, however, of the coalfields along the southern margin of the Satpura-Gondwana basin to indicate that the available coal resources of this tract are greater than previous estimations.

Dr. Fox's traverses have led him to believe that coal-bearing rocks will be found at no great depths in the valleys of the Denwa, Sonbadra and Tawa rivers to the southwest and southeast, respectively, of the Pachmarhi hills. He is in particular impressed with the possibility of a hidden coalfield in the low ground immediately north of Hasdiwari and south of Delakhari. The strata in this area are unfortunately somewhat interrupted by the great masses of intrusive dolerite of Deccan Trap age which are there very conspicuous.

The hard sandstones forming the anticline seen a mile south of Tindi near Khairi, 10 miles west of Mohpani, are thought possibly to be associated with the coal measures of the south Narbada Valley; if so the area may be worthy of prospecting. Dr. Fox is of the opinion that the numerous bore-holes which have been put down near Gotitoria have proved little, and that the location of some of the bore-hole sites in this area were not as wisely chosen as they might have been. He is unable to agree with the view that the coal seams which were found further to west near Bagra and again near Lokartalai are in strata of the Jabalpur beds. His opinion is the same as that originally held by Mr. W. T. Blanford and supported by Mr. J. G. Medlicott: it was subsequently discarded by Mr. H. B. Blanford. This view is that these coal seams are in strata of Damuda age and possibly the equivalent of the Barakar stage. Although these coal-seams belong most probably to the same series as those of Mohpani, they are much thinner; the coal, moreover, is of poorer quality and may prove incapable of profitable exploitation.

The conclusions that the upper Gondwana rocks of this region are much thinner in total amount and form a repeated series of different varieties of sediments of nearly the same age, have been supported by the traverses made by Messrs. H. Crookshank and A. K. Banerji and also by the discovery of old field maps by Dr. V. Ball. These conclusions agree with the original opinions expressed by Mr. J. G. Medlicott previous to the drastic revision instituted by his brother.

The present view is that the topmost sandstones of Tamia and the southern part of the Pachmarhi hills are the same as those capping the highest hills south of Mohpani which have been called Jabalpur beds. The banked conglomerates and limestones of the Bagra beds are a shore facies of the sandstones and red and variegated clays of the so-called Denwa stage and that these again are equivalents of the Motur Stage. There is a great variation in the proportion of sandstones to red clays in the Denwa-Motur group as these beds are traced southwards and south-westwards from the Anjan gorge south of Fatehpur. Sometimes the clays are more abundant, as around Jhispa and in the Dudhi Valley between Khapa and Bamani; in other cases the clays are very subordinate, as in the northern part of the Pachmarhi hills south of Singanama.

Below these beds there are further clays and sandstones, such as those of north Delakhari; these are probably the equivalents of the Alimod beds and possibly the representatives of the Kamthi beds of Nagpur and the Panchets of the Damuda valley.

Under these strata occur the Bijori beds, which are identifiable with the Raniganj stage of the Bengal coalfields. There is, then, some obscurity in the succession owing to lack of exposures, and to the overlap of the Motur facies of the Denwa. The next beds seen are the coal measures of the Pench valley, etc.; these lie on the Talchirs.

The field work shows that there must be a considerable stratigraphical break between the Damuda and the Mahadeva series in the Satpura basin, particularly along the margins of the basin both to the north and south. The younger beds have been more completely removed by denudation along the south of the basin, possibly because these beds were thinner in the south, and thus the old rocks are better exposed.

The coal seams appear to be best developed in the middle strip, from north to south, about 15 miles wide from Mohpani to Jamai. To the east as well as to the west the seams become thinner and appear to deteriorate in quality as a fuel.

The general structure from north to south is that of a basin but the beds have been subjected to some compression as there are three or four anticlinal axes trending 75° E. of N.—75° W. of S. There are several faults parallel to the same direction; most of these throw down to the south but there are strong main faults

in the north and in the south which appear to throw the beds down to the north.

There is also a general low dip to the east and to the west from a N. and S. line trending through the Pachmarhi hills The whole of the Gondwana strata have a tilt to the north and this is the most conspicuous feature, Talchir .beds being found at an altitude of 2,500 feet along the southern margin and similar beds at 1,200 feet along the northern margin of the basin.

Mr. A. K. Banerji, on his return from deputation in London, was directed to join the Coalfields party in February and was given the Mohpani coalfield to re-survey. This re-survey has demonstrated the excellent nature of the original investigation carried out by Mr. H. B. Medlicott in 1869-70. The area is complicated in structure and large-scale maps would be necessary to elucidate all the minor details of folding and faulting. From a commercial point of view it is doubtful whether the preparation of such maps would be justifiable in view of the disturbance to which the beds have been subjected. No fresh discoveries of workable coal have been made and the question of the northward extension of the coal-bearing series beneath the Narbada alluvium has yet to be answered. Mr. Banerji is inclined to believe that, since the general structure is that of an anticlinal flexure, such a hidden extension to the north is probable but that it is very unlikely to extend to any distance.

Shahpur coalfield, Betul district; Central Provinces.

The Shahpur coalfield comprising the area of Barakar rocks in the northwestern part of the Betul district of the Central Provinces, was re-investigated by Mr. Gee. Up to the present efforts to exploit the area have met with very limited success, but it would be unfair to judge from past results since no attempts to prove the succession by boring have been carried out. Efforts appear to have been concentrated—in most cases in ignorance of the geological structure of the seams—on the sinking of a number of diggings within a very short distance of a coal outcrop observed in the bank of a neighbouring stream-course. Such primitive attempts, regardless of the damage done to the seams by flooding during the rains, have not unexpectedly met with little success; many of them were inaugurated during the boom season of 1919-20, and the workings have since been abandoned.

A previous survey of the field was carried out by Mr. Medlicott during the field-season of the year 1875 and, during the present

inspection, no great differences as regards the extent of the various divisions of the Lower Gondwana rocks of the area were encountered. It was from the point of view of the structural details within the field that the conclusions arrived at were at variance with those of Mr. Medlicott.

The strata on the whole dip to the north or north-east at a low to moderate angle, but their present extent at the surface is governed mainly by the numerous faults which traverse the area. Two systems of faulting occur; an east-to-west series together with a number of cross-faults cutting these obliquely from north-west to south-east. The throw of these faults appears to vary rapidly so that they affect considerably the horizon of the outcropping strata along the line of faulting.

A very close connection appears to exist between these vertical displacements and the basalt and dolerite intrusions which intersect the area, the main dykes following very closely the lines of faulting. The occurrence of tracts of ferruginous, silicified, and quartz-veined sandstones in similar intimate association with the intrusives and with the faulting of the field, was noted.

The succession of the Gondwanas represented in and around the Shahpur coalfield include types ranging up to the Motur horizon. The Talchirs rest against the Archæans of the highlands to the south. In some instances they pass conformably up into the Barakar division, but in many cases the two series are separated by faulting. The Barakar strata include a lower horizon of transitional beds in which thin coal-seams occur; these are followed by mass-grey felspathic sandstones and grits, in the upper part of which several coal-beds are included. The Barakar sandstones pass upwards into a series of moderately soft greenish sandstones which give place above to true Motur types, in which red and green clays containing calcareous nodules are intercalated. These strata are all well exposed in the Tawa River and its tributaries.

No boring records being available the only source of information regarding the coal-seams of the field is the limited surface outcrops which occur. In the eastern, Dulahra, portion of the coalfield five seams ranging up to 5¾ feet in thickness are observed in the Tawa River and in the diggings to the north. The thicker seams include bands of shaly coal and are of very poor quality; the lower seams of 2½ feet and 2¼ feet in thickness show an improvement, containing only about 20 per cent. ash. Two thin seams were met with

in the lower Barakars near the Machna tributary a short distance from Shahpur; whilst in the same river-section two other coal-seams about 3 feet in thickness, and apparently of better quality, were seen in the upper Barakars. Again, at Gurgunda in the western part of the field a 6-foot-seam, including a band of shaly coal had been worked for a short period. The outcrops of the coal are therefore not very promising, though it is possible that investigations by boring might bring to light other workable seams.

Gajandoh coalfield, Chhindwara district; Central Provinces.

The Gajandoh coalfield in the Chhindwara district, about 2 miles north-north-east of the town of Umreth, was inspected by Mr. E. R. Gee. Here the Barakars crop out over an area of about $\frac{1}{10}$th square mile. To the south the Archæan granites and gneisses are faulted down against the coal-bearing series; while to the north-east and west a thin strip of red Motur clays followed by basalt lava-flows rests on these lower Gondwana beds. The Barakars are represented by massive sandstones with grey shales. One coalseam outcrops in the Thaonri, just north of the boundary fault; this had been dug from a short cutting which is now flooded, and only one foot of the seam was visible. The seam dips at a fairly steep angle to the north, but there is evidence of a decrease of the inclination as we go northwards away from the fault.

Ellichpur; Central Provinces.

The sandstones quarried at Bairam near Ellichpur were examined by Mr. Gee who describes them as medium-textured and gritty grey felspathic types some of which resemble in lithology many of the typical Barakar sandstones associated with the coal-seams. They however contain no carbonaceous bands, though purple argillaceous intercalations occur in the upper part of the succession. In these higher horizons they pass into conglomerates containing red jasper pebbles. Resting apparently conformably on this arenaceous series are thicker purple clays, followed by a purple-grey limestone of infra-trappean horizon. It is therefore strongly suggested that the sandstones belong to the higher Gondwana horizons, probably corresponding to the Kamthis of other areas.

Central Tawa Valley; Central Provinces.

The tract of Gondwana strata known as the Patakhera coalfield in the south-eastern portion of the Betul district, forms a continuation to the east of the Shahpur coalfield, and was inspected by Mr. Gee. The Talchir beds crop out to the south of the Lodardeo-

Rawandeo ridge as far east as the village of Bagdona. To the south they rest on the gneisses of the Ranipur-Gatakhera tract. They include the same succession as in the Shahpur field, the conglomerates of the lower part of the series being well-exposed in the Phopas and neighbouring stream-courses and including boulders which appear to be definitely striated.

To the east these Talchir beds pass, usually quite gradually, up into the Barakar beds which outcrop in the Ranipur Forest. A few thin coal-seams occur just to the east of Bagdona, and these appear to come in in the lower Barakar horizons. But in the Pathakhera Nala several seams of workable thickness crop out, including one seam 10 feet in thickness; the dip, however, in this stream is as steep as 50°.

To the north of the Barakar beds, which appear to be partially repeated by an east-to-west fault, softer greenish types crop out with no included carbonaceous bands. A coal-seam again crops out in the Tawa River to the north of the tract, to the south of Jungikhapa. Just south of this coal-outcrop a trap dyke can be traced discontinuously right across the tract following an east-to-west direction, and marks the line of a second fault, causing the incoming of the Barakar beds to the north, evidenced by the coal-seam of the Tawa River.

The eastern boundary of the field also appears to be a faulted one, the fault following the Tawa as it flows northwards past Bichhwa. This fault brings the Pathakhera Barakars against the Talchirs to the east.

Lodardeo-Kilandeo area; Central Provinces.

In the Lodardeo-Kilandeo area the post-Barakar sandstones and intercalated clays were found by Mr. Gee to be largely represented. To the east of the Dulahra coalfield, and again in the Tawa River to the north-west of the coal outcrop south of Jungikhapa, a series of greenish sandstones with very thin carbonaceous intercalations occur. Above these beds rest the typical Moturs with bands of red and green clays. These are well-exposed to the north of the Tawa River around Ghogri, and in the Dagdaga Nala, and cover a part of the area previously mapped by Jones as Barakar. Above these clay horizons thick sandstones are well-exposed in the hillslopes up to Kilandeo Peak. They vary in type, a yellow siliceous fine-grained variety being prominent.

In the foot-hills of the Bamhanwara-Khapa area the uppermost Talchir sandstones are prominent. Evidence of small faults causing

their repetition to the north were observed by Mr. Gee in the stream-courses of these hills. In the north-western part of the area these upper Talchir beds appear to be faulted against the post-Barakar strata by a displacement down-throwing to the north. In the streams to the north-west the Barakar beds including several thin coalseams crop out above the Talchir series. Faulting, usually in the vicinity of trap-dykes, has affected the outcrops of these beds in various ways.

Bamhanwara-Khapa area; Central Provinces.

North Arcot district, Madras; and Kolar, Mysore.

In November 1924, Dr. Fermor, while visiting the North Arcot and Salem districts in the Madras Presidency in order to assist Mr. Vinayak Rao with certain difficulties, took the opportunity of examining, under the guidance of Mr. T. Pryor, mining adviser to Messrs. John Taylor & Sons, the conglomerate belt that stretches from Kolar into North Arcot, and concerning the nature of which there does not yet appear to be complete agreement amongst geologists. Dr. Fermor found that in the Bisanattam Nala this belt provides good evidence of autoclastic phenomena. An acid tongue, regarded by the Mysore geologists as belonging to the Champion gneiss, projects into hornblendes schists of Dharwar age, xenoliths of which are found in the gneiss, proving thereby the intrusive character of the gneiss. This gneiss has been crushed with the production of a pseudo-conglomerate consisting of 'pebbles' of gneissose granite, and sometimes of xenolithic hornblende-schist, in a more schistose gneiss matrix In one place the gneiss has been crushed throughout to a fine-grained schistose gneiss with occasional "pebbles" of less crushed gneiss. In another place exposures are seen of granite veins injected *lit-par-lit* into hornblende-schist, the granite often swelling into lenticles in the manner so often seen with acid intrusive veins. Such an occurrence seems specially liable to conversion into an autoclastic conglomerate, and in another exposure this is seen to have happened; the lenticular swellings have become most deceptive "pebbles" and "boulders" with the thinner connecting portion of the granite squeezed out, leaving acid "pebbles" in a matrix of hornblende-schist, a result almost the reverse of that noticed above, in which the "conglomerate" showed acid and basic "pebbles" in an acid matrix. All stages in the formation of these conglomerates are to be found in the Bisanattam Nala, whose fine set of exposures support in no small

measure the view held by the Mysore Geological Department as to the autoc'astic nature of the Kolar conglomerate belt.

Dr. Fermor and Mr. Vinayak Rao also visited Sakrasanhalli some 4 miles S. S. W. of Bisanattam station and in the Kolar district of Mysore State; at this locality there is an occurrence of black manganiferous marble with associated manganese-garnet rocks, which in the opinion of Mr. Jayaram of the Mysore Geological Department may, with certain other rocks, belong either to a lower division of the Dharwars than has hitherto been recognized in Mysore or to a still older series. Dr. Fermor observed a close resemblance between these rocks of Sakrasanhalli and members of the Sausar series in the Central Provinces; and should detailed stratigraphical work confirm Mr. Jayaram's suggestion concerning the position of the rocks of Sakrasanhalli, this will agree with the suggestion previously advanced by Dr. Fermor that, if the hornblende-schists of the two areas can be correlated, the majority of the Dharwars now called the Sausar series of the Sausar *tahsil* must be regarded as older than those hitherto described from Mysore.[1]

North Arcot and Salem, Madras.

Rao Bahadur M. Vinayak Rao continued his survey of North Arcot and Salem in Madras on standard sheets (1 inch=1 mile) Nos. 57 $\frac{L}{1}$, $\frac{L}{2}$, $\frac{L}{6}$ and $\frac{L}{10}$. No representatives of the manganiferous marble observed in the neighbourhood of Sakrasanhalli were noticed to the south, but about 2½ miles south of the Samalpatti railway station on the South Indian Railway thin bands of limestone—some of them better described as of marble extend for a distance of about ten miles, and may be correlated with the manganiferous marble These would thus form the oldest rocks of the Dharwars in this area. According to Mr. Vinayal Rao some of the limestones approach in composition the calc-granulites of the Chhindwara district, Central Provinces. Hornblende granites were found to be among the earliest intrusives in the Dharwars.

In the neighbourhood of Krishnagiri in the Salem district there occur bands of an even-grained pink granite which is intrusive in the older gneisses. They are probably of the same age as the Closepet granites of Mysore and the Bellary granites.

[1] *Rec. Geol. Surv. Ind.*, vol. LIII, p. 23.

The Javadi Hills east of Vaniyambadi in the North Arcot district probably formed part of the Mysore plateau. The Palar valley, which separates them, is thought to have been formed during the intrusion of the charnockites in this area. The charnockites are found as thin bands on the Mysore Plateau, and do not appear to extend north of the latitude of Bangalore.

The conglomerates in the Dharwars east of Bisanattam railway station are considered by Mr. Vinayak Rao to be autoclastic conglomerates.

Rajputana.

Dr. A. M. Heron, in charge of the Rajputana Party, while on his way to inspect the work of Messrs. A. L. Coulson, E. J. Bradshaw and B. C. Gupta, in the Bundi State, took the opportunity of mapping, with the assistance of Sub-Assistant B. C. Gupta, the country adjoining the Great Boundary Fault of Rajputana (in standard sheets, Central India and Rajputana 203, 234 and 235).

The rest of the season was occupied by him in the geological survey of standard sheets, Central India and Rajputana Nos. 171, 204, 205, and 206. Portions of these, included within the States of Gwalior and Tonk (Nimbahera *pargana*) had previously been surveyed by Mr. H. C. Jones before the war, and are included in the following description.

A novel feature of this area is the manner in which the strike of the rocks, which, throughout Rajputana north of a line drawn from Udaipur City to Chitorgarh, is almost invariably N.E.-S.W., here swings through N.-S. to N.W.-S.E., almost as if the western lobe of the great Vindhyan plateau, on the extreme west of which is built the famed fortress of Chitor, had formed a block around which the older formations had been bent, the Great Boundary Fault itself being also concentric to this curvature.

The oldest rocks appear to be an assemblage of shales, slates and phyllites; these are lithologically similar to, and are continuous along the strike through the Bundi State with rocks which in southern Jaipur were tentatively attributed to the Gwalior system by Dr. Heron. (*Mem. Geol. Surv. Ind.*, vol. XLV, pt. 2, pp. 138-145.) Evidence is accumulating that these so-called Gwalior rocks pass gradually into the highly altered Aravalli types in the direction perpendicular to their strike, by increase of metamorphism as the centre of the ancient Aravalli range is approached.

Near the Great Boundary Fault they are shales, but, as they are followed to the west or north-west away from the fault and across the strike, they first assume a simple cleavage without mineral modification and then become successively phyllites with veins of intrusive quartz, chlorite and muscovite schists with staurolite and finally garnetiferous mica-schists with pegmatite veins in *lit-par-lit* injection—composite banded gneisses. It thus appears possible that the lower, argillaceous division of the so-called Gwaliors of southern Jaipur are, as Dr. Heron at first believed, unaltered Aravallis, which have escaped metamorphism owing to their remoteness from the core of the ancient range.

In the Jaipur area these beds are succeeded upwards conformably by a series of quartzites (the Ranthambhor quartzites) interbedded with the shales and dolerite sills, which have a considerable resemblance to the true Gwaliors of the type area. These also have their representatives in the present area, at Mandalgarh and Bari Sadri, in large synclines of ripple-marked, pebbly quartzites; they have been mapped by Hacket as Vindhyans and Delhis, but they resemble neither and are conformable on the underlying shales and slates.

Large expanses of a medium-grained pink granite, the ferro-magnesium component of which is secondary chlorite, and which is devoid of pegmatite veins, interrupt the slate areas. This is distinct from the post-Delhi and post-Aravalli (pre-Delhi) granites of northern Rajputana. Its exposed contacts with the slates are few, but, where seen, there is great mechanical disturbance of the slates without any metamorphism, and in no case was a trace of basal arkose or conglomerate seen. The balance of probability is, according to Dr. Heron, that the granite is intrusive in the slates. Both are traversed by dykes and, in the slates, by sills of olivine dolerite altered in places to epidiorite.

The granite itself has suffered pressure metamorphism towards the west and the Berach River bed affords an admirable demonstration of its gradual transition into a grey, slabby gneiss. Slates, granite and dolerite are but poorly exposed, and excavated material from wells which pierce the alluvial mantle has often to be relied on for their mapping.

Rising boldly above the plain are numerous steep ridges of massive white quartzites (sometimes quartz grits), seldom showing bedding, but seen under the microscope to have been a true sedi-

mentary sandstone composed of rounded quartz grains, with secondary quartz in optical continuity with that of the grains, filling the interspaces to form a mosaic. These quartzites are quite distinct from the Mandalgarh and Bari Sadri quartzites.

The abundant and highly resistant débris which they shed conceals most effectually their junctions with the slates around their bases. In one or two favourable sections, however, apparent complete discordance was observed by Dr. Heron, not however as if the quartzites lay with an erosion unconformity upon the slates, but as if they were inset at a high angle into the slates, an attitude which Mr. Middlemiss has noted in Idar.[1]

The apparent dip of the slates is, however, merely a cleavage dip, almost invariably at high angles to the W. or N. W., and the true stratification, rarely visible, may be at any angle to the cleavage. Despite these deceptive appearances to the contrary, it is believed that the white quartzites are conformable members of the same sequence as the slates.

The manner in which such quartzites "make and break," ending abruptly and appearing again suddenly along the strike, is a puzzling commonplace in such regions. In few cases can it be explained by the concealment of missing portions under alluvium, by normal dip-faulting or by the quartzites being the roots of synclines or crests of anticlines closely compressed and steeply pitching. The phenomenon is believed by Dr. Heron to be due to disruption and actual moving apart of the quartzites in a plane perpendicular to the direction of tectonic pressure, the slates being forced between the separated sections. Wedge-faulting (*schuppenstruktur*) may also have contributed, by cutting out the quartzites in some places, and in others duplicating them.

Four miles west of Barundni shales lie with an indubitable erosion unconformity upon the granite, and N. and N. W. of Chitor quartzites and arkose grits have the same clear relationship to it, but it is quite uncertain that these rocks are of the same age as the Gwaliors or Aravallis above described—there is a possibility that they are younger. The quartzites near Chitor rest, with a basal arkose and conglomerate, on granite to the east, and dip westwards under slates, the various beds of quartzite ending abruptly *en echelon* against slates, in a way which indicates wedge-faulting.

[1]*Mem. Geol Surv. Ind., vol.* XLIV, pt. 1, pp. 75, 109-111.

In the south of the area inky-purple grits and greywacke, "the Khardeola grits," rest with a somewhat obscure unconformity upon the slates, having at places along the supposed unconformity a thin, basic, devitrified vesicular lava, the "Khairmalia amygdaloid." As the Khardeola grits appear to be free from dolerite intrusions, Dr. Heron believes that the Khairmalia amygdaloid is the effusive representative of the dolerite hypabyssals.

The next formation is the buff, or more rarely grey, "Bhagwanpura limestone," which extends north and south throughout the area in a broad band, overlapping both the Khardeola grits and the underlying slates, quartzites and granite. It is full of chert and quartz, and the unconformity at its base is locally marked by bands of rounded pebbles of quartz, jasper, quartzite and more rarely granite, with much of the angular quartz débris produced by the disintegration of granite. Owing to the obscurity of the dip, the thickness of the lime-stone can only be guessed, but is of the order of a thousand feet. At its top it passes up into shales, which are however usually concealed by the Sawa grit.

Parallel to the Bhagwanpura limestone band to its east, the "Sawa grit" and the "Sawa shales" form a narrow discontinuous ridge. The grit, which is mainly composed of subangular chert and white quartz fragments, lies with a recognizable but not violent unconformity upon the Bhagwanpura limestone, with outliers upon the older series, and passes up conformably into the Sawa shales, which are white, siliceous and chert-like.

The relation of the Sawa shales to the "Binota shales," the next formation, is doubtful, since the southward extension of the Great Boundary Fault seems to pass more or less along their junction, and exposures are poor. For four miles along this line, the Sawa grit and shales are cut out by the fault, and the Bhagwanpura limestone is inverted over the Binota shales by the thrust, resting on them at a low angle.

The "Binota shales" are exposed in another north and south band parallel to the Bhagwanpura limestone and the Sawa beds, to the east of those, and are in their turn overlapped to the east by the Jiran sandstone and the Vindhyans. They are a monotonous series of brownish shales, sometimes rather sandy and micaceous, with occasional thin ferruginous layers, and are disposed nearly horizontally in low rolling folds.

The "Jiran sandstone"—the "Delhi quartzite" of Hacket in his references to this particular area—is 100-200 feet in thickness, and in it three zones can be distinguished, the lowest pale grey mottled with deep purple, the middle one coloured grey and purple in about equal amounts, and the uppermost of a purple colour almost to the exclusion of grey. Near Bari the lowest beds are very coarse-grained and have been described by Hacket as conglomeratic. The sandstone is disposed in four anticlines and three synclines, with their axes running north and south; near Choti Sadri they unite to form a plateau in which dips are practically horizontal. In the present area the sandstone overlies the Binota shales with every appearance of conformity, but eight miles to the south, outside this area, a very clear unconformity between the two was seen by Dr. Heron, in a group of flat-topped hills near Wardhal, the horizontal sandstone capping them, with the shales dipping to the west at 5° in the undercliff.

In most of the Vindhyan area the Kaimur sandstone with its basal conglomerate marks the bottom of the Upper Vindhyans, and below this the lower Vindhyans may or may not occur, but where they do so, there is always a slight unconformity between them and the Kaimur. Here the lower Vindhyans proper are absent, but beneath the Kaimur sandstone (there is no conglomerate) more than 1000 feet of beds intervene between it and the base of the Vindhyans, in a perfectly conformable sequence, and these must be classed as Upper Vindhyans.

All these strata are folded in the same fashion—in narrow anticlines and synclines with north and south axes. The Kaimur sandstone forms a bold plateau, with oval outlying patches representing troughs of denuded synclines, on the westernmost of which stands the Fort of Chitor; the other stratigraphically lower formations, shales and limestone, occupy the level, featureless plain below.

At the base of the long Vindhyan succession is the Khori-Malan finely conglomeratic sandstone, 30-40 feet thick, lying on both the Binota shales and the Jiran sandstone, with occasional large rounded boulders. It is a curiously local formation, occurring practically only in the vicinity of Khori and Malan. Elsewhere the purplish Nimbahera shales, 150 feet thick, rest directly on the Jiran sandstone or the Binota shales; in the latter case it is hardly possible to separate them, for they are lithologically almost identical and both are poorly exposed.

The Nimbahera shales pass upwards into the Nimbahera limestone, through 30 feet of passage beds—reddish-purple limestones. The remainder of the limestone, 450 feet in thickness, is pale grey with partings of fawn colour, and is thick-bedded in layers 1 or 2 feet thick—a smooth, hard rock, almost a lithographic stone. It is extensively quarried, particularly round Nimbahera. Sawa and Khori, zones more thinly bedded than the normal being favoured, so as to yield slabs about 4 inches thick. Jointing is regular, the joint-planes running 20°W. of N. and 80°E. of N. approximately; slabs 2 or 3 yards square can be extracted. Where folding stresses have been exceptionally strongly felt, a vague cleavage has been initiated at an angle to the true bedding.

The Suket shales succeed the Nimbahera limestone conformably, and pass upwards without discordance into the Kaimur sandstone, the transition being well seen on the road leading to the Chitor Fort. They form the undercliffs to the Kaimur scarps, and a broad belt encircling their base, with two long narrow synclines extending some miles south from Chitor, folded into the Nimbahera limestone. Away from the scarps the Suket shales are considerably puckered, but close below the top of the scarp they lie regularly, owing to their being protected from crumpling by the rigidity of the competent sandstone above.

The Kaimur sandstone is a uniformly fine-grained rock, more a quartzite than a sandstone, pale grey in colour blotched with brownish-purple. Usually it is thick-bedded, while a roughly quadrangular jointing gives rise to great vertical monoliths on the face of the bold scarps which the Kaimur forms.

In the extreme south-east, around Neemuch, Deccan Trap, with patches of laterite upon it, overlies all the older formations and forms fertile plains of cotton-soil. Inliers of the Jiran sandstone project in places through it, and outliers of the trap extend for some miles north and west from the main expanse as characteristic flat-topped hills in which is exposed a thickness of about 50 feet of trap, all belonging to the one flow.

The Great Boundary Fault of Rajputana has now been followed throughout its entire visible length, from where it is interred below the Gangetic alluvium near Fatehpur Sikri in the north to where it disappears below Deccan Trap on the frontiers of Mewar and Partabgarh in the south. Its course through the Karauli and Jaipur States has been described by Dr. Heron (*Mem., Geol. Surv. Ind.*, vol.

XLV, pt. 2, pp. 169-177); Messrs. Coulson and Bradshaw have this season traced the portion which lies within the Bundi State, and Dr. Heron the remainder lying in the Mewar territory.

The faulting appears seldom or never to consist of a "clean-cut thrust," but usually comprises several planes of movement, sometimes diverging widely, with large blocks of unfractured country between; in other places it is a band of shearing and crushing. As shewing an example of the latter the "Datunda quartzite" of Hacket may be cited. This extends as a ridge, varying greatly in height and in width, from south of Bundi City to beyond Mandalgarh, between the Vindhyans on the south-east and the Gwalior shales on the north-west. It appears to be merely a line of wedges of shattered lower Bhander sandstone included in the fault. Along this portion of the fault it is usually the Lower Bhander sandstone or the Lower Bhander limestone which adjoins it to the south-east. From Mandalgarh to Chitor, the fault is no longer parallel to the general strike of the Vindhyan folds, but oblique to them, so that various members of the Vindhyan scale abut in turn against the Gwaliors or the granite.

At Chitor the fault takes a southward trend and leaves the Vindhyans, passing, as far as can be ascertained in poorly exposed strata, just to the east of the Sawa grit and shales, which are in consequence much crumpled and frequently inverted, but much of this section has to be guessed at.

Bundi State; Rajputana.

The survey of Bundi State, Rajputana, commenced in the previous field season, was continued uninterruptedly until its completion at Lakheri by Mr. A. L. Coulson. Sub-Assistant B. C. Gupta assisted Mr. Coulson in the survey. Dr. Heron, Mr. Bradshaw and Mr. Gupta joined up with Mr. Coulson towards the end of December, and sections at Datunda, Sarorda, etc., were inspected by Dr. Heron during this period. Mr. Bradshaw and Mr. Coulson worked with joint camps for certain periods.

In tabular form, with the youngest deposit above, the rocks present in the area are as follows:—

C. Recent and Sub-Recent (Alluvium, etc.)

B. Upper Vindhyans.

Upper Bhander: { **11. Upper Bhander Shales and Grits.**
10. Upper Bhander Limestone.
9. Upper Bhander Sandstone. }

	8. Sirbu Shales.
	7. Lower Bhander Sandstone.
Lower Bhander:	6. Samria Shales.
	5. Lower Bhander Limestone.
	4. Ganurgarh Shales.
Upper Rewa:	3. Upper Rewa Sandstone.
Lower Rewa:	2. Jhiri and Panna Shales and Lower Rewa Sandstone.
Upper Kaimur:	1. Kaimur Sandstone and Conglomerate.

A. Gwaliors.

The basement rocks of the area- which comprises parts of survey sheets, Central India and Rajputana (1 inch = 1 mile) Nos. 234, 265, 266 and 291 are more allied to the Gwalior than to the Aravalli type, though it is still uncertain what the relationship of the Aravallis to the Gwaliors really is or, indeed, whether the two are really distinct.

The Gwaliors consist of limestones, phyllites, shales, sandstones, quartzites and greywacke, with intrusive reef-quartz, pegmatites and, to a lesser extent, trap. A boulder bed has been recorded in the Gwaliors at Dhaneum.

The Upper Vindhyans rest unconformably upon the Gwaliors and in no case was pegmatite found intruding the Vindhyan rocks.

The basal bed of the Upper Vindhyan is the Kaimur conglomerate, and upon this is the Kaimur sandstone, the only two members of the Kaimur division of Mallet represented in the Bundi area. The Kaimur conglomerate contains pebbles of white reef-quartz, red and black jasper, fragments of shale, sandstone and felspar and also white and black chert. The Kaimur sandstone has a distinct reddish colour. Definite sandstone and conglomerate were found in the Gwaliors in the extreme southwest of Dr. Heron's map of South-Eastern Rajputana, and Hacket's Kaimurs have had to be reduced by Mr. Coulson to one-third of their amount. The average thickness of the conglomerate is about 6 to 8 feet and that of the sandstone 100 to 120 feet.

The Panna and Jhiri shales are persistent, if somewhat thin beds, whilst the Lower Rewa sandstone is very sporadically developed. This last is usually a light-coloured flaggy sandstone. The thickness of the Jhiri shales varies to a maximum of 100 feet. The upper beds of the Jhiris contain limestone bands.

The Upper Rewa sandstone attains a thickness of 300 feet and is best developed near Bundi. Towards the north-east, it becomes calcareous and definite limestone bands appear in the rock.

The Ganurgarh shales attain a thickness of about 600 feet. Associated with the shales are very definite limestones and quartzites which latter are best seen near Lakheri.

The Lower Bhander limestone was found by Mr. Coulson to be the most important zoning division in the Upper Vindhyans. Characteristically it is from 200 to 300 feet thick, a thin-bedded grey-blue, pink, or purplish rock. It shows very little crystallisation and its chief impurities are quartz and iron-oxide. Mr. Coulson notes that it appears to have been deposited from calcareous solutions under marine conditions, either before the dawn of life or under conditions which did not permit of the preservation of organic remains. No fossils have been found in the stone though it is ideally suited for their preservation. It is at present being extensively worked for lime and cement by the Bundi Portland Cement Works at Lakheri; numerous analyses show that the limestone is eminently suitable for the manufacture of cement.

The Samria shales, so named by Kishen Singh from their occurrence at Samria in Mewar, overlie the Lower Bhander limestone. They form a thin and impersistent member, though at times developed to the extent of 100 feet or so. The upper part of the shales sometimes contains a thin, hard, dark buff, limestone.

The Lower Bhander sandstone is the most strongly developed member of the Upper Vindhyans and attains a thickness of about 2 600 feet. It, like the Kaimur and Rewa sandstones, would be more properly termed a quartzite. The lower beds are usually fine-grained and red; these are followed by a grit, and this by a very hard white quartzite which resembles white reef-quartz.

The Sirbu shales were found to have a total thickness of about 500 feet; associated with them are definite limestones which, however, are usually more shaly than the Lower Bhander limestone. They are fissile shales with a good cross-jointing but the same may be said of all the Upper Vindhyan shales.

The Upper Bhander sandstone was found by Mr. Coulson only in the extreme north-east of Bundi State. Its total thickness is about 80 feet or so. It conformably overlies the Sirbu shales of the Lakheri area and has always been considered as the highest member of the Upper Vindhyans. In Bundi, however, this sandstone is conformably overlain by a limestone and this again by a strong series of shales and grits. The names of Upper Bhander Limestone and Upper Bhander Shales have been given to these new stages.

There can be no question of the conformity between these stages as many sections may be seen in the various river beds.

The Upper Bhander limestone is a very fine-grained rock with usually a secondary and coarser crystallisation of calcite. It breaks with a conchoidal fracture and usually shows concretionary markings. The limestone has practically no overburden and so can be easily worked. It is at present being quarried for lime. An analysis of the rock shews fewer impurities and slightly more magnesia than the Lower Bhander limestone.

The Upper Bhander shales vary little from the other shales of the Upper Vindhyans. At their top, however, there are a few grits and sandstones with interbedded shales.

Alluvium covers a great area to the south of the Vindhyan ranges.

The general strike of the area coincides with that of the Gwaliors to the north-east, *i.e.*, N. E. to S. W. The same tectonic agencies which caused the folding of the Aravallis, Delhis and Gwaliors, persisted to the close of the Vindhyan epoch. The folding is no doubt to be regarded as the effect of pressure from the north-west against the shield of peninsular India.

The Great Boundary Fault was followed by Mr. Coulson through Bundi for about 70 miles and continues into Mewar for a further distance of 80 to 90 miles. It has been considered as a reversed fault with a throw to the north-west, usually faulting the Gwaliors against the Lower Bhander sandstone, and responsible for the metamorphism of the Datunda quartzite. Where this quartzite is formed from the lower Bhander sandstone, the boundary fault is considered to be of the nature of several parallel faults. There are other great faults in Bundi, *viz.*, that of Motipura, the Ramgarh horseshoe fault, the Indargarh-Bundi fault, etc. The area to the south-west of Bundi has not been so disturbed and the strata gently undulate in synclines and anticlines.

Sirohi State; Rajputana.

After completing the survey of Bundi, Mr. A. L. Coulson commenced the survey of Sirohi State in March. In all, some 255 square miles were geologically surveyed, some 77 square miles of which constituted the Mount Abu area, the remaining 178 being in the east of the State, bordering Jodhpur and Mewar (portions of sheets, Central India and Rajputana, Nos. 96, 97, 118, 119, 1 inch=1 mile). The rocks shewed a marked similarity to the rocks noted in the *istimrari* estates of Ajmer. (*Rec., Geol. Surv. Ind.*, vol. LVIII, pp. 66—68, 1925.)

As in that locality rocks resembling both Aravalli and Delhi occurred.

The fundamental schists have been provisionally referred to the Aravalli system. They are so profusely intruded by basic rocks, gneiss, granite and pegmatite that an enormous variety of types has resulted. Generally, according to Mr. Coulson, there are two classes, one in which there has been a relatively small influx of material and in which the resultant rock is the normal product of the metamorphism of the ancient argillaceous rocks, *e.g.*, biotite-schists, etc.; the other, in which so great a quantity of extraneous material has been intruded that the product can only be called a schist for purposes of mapping. Simple silicification gives mica-quartz-schists, but where there is abundant pegmatite, the resultant rock, with the pegmatite as discontinuous entities, resembles a gneiss to some extent.

The calc-rocks cover some 42 square miles and are of economic importance. They are usually impure limestones with biotite, quartz, muscovite, iron-oxide, apatite, zircon and sphene as impurities. Dr. Heron has noted the possibility of their being the equivalent of the "Ras" limestones (Archæan or Aravalli). They vary greatly in hardness and mineral contents, and are intruded, though to a lesser extent than the schists, by the amphibolitic rocks.

The basic intrusive series intruding the calc-rocks and the schists comprise epidiorites, hornblende-schists, pyroxene-granulites, amphibolites, etc. They all appear to be pre-Gneiss in age; in the Ajmer *istimrari* estates, some dolerites were post-Gneiss but dolerites have not been recognized in this area.

There is a great resemblance between the gneiss of the plains and that of Mount Abu. The Abu gneiss varies greatly mineralogically and texturally but the usual type is a biotite-gneiss. It contains innumerable basic xenoliths of amphibolites, which have made the gneiss slightly more basic than that of that plains.

There is a large outcrop of some 8½ square miles of granite near Waloria stretching into Mewar. It differs markedly from the gneiss in that the dominant felspar is orthoclase instead of microcline and in the presence of vertical jointing, which gives rise to physiographical features different from the rounded tors of gneiss. Dr. Heron considers it to be the same as the "Berach" granite. In no place could the granite and gneiss be found together.

The quartzites are interesting in that they are of metasomatic origin. In only a few places have they conformable relations with the schists, etc. Their boundaries, as a rule, run haphazard across the schists and calc-rocks. They appear to be derived from the solutions which accompanied the pegmatites of both gneiss and granite, into which pegmatites they sometimes pass uniformly. A brecciated quartzite was found at Sanwara, shewing faulting to have taken place after their formation. The pegmatites belong both to the gneiss and to the granite. The usual minerals found in them are quartz, felspar, garnet, tourmaline, muscovite, etc.

Mewar State; Rajputana.

The first portion of the field season was spent by Mr. E. J. Bradshaw in the geological mapping of Bundi State, in company with Mr. A. L. Coulson. In the month of March the geological survey of Mewar State was commenced, the area surveyed being a portion of that shown on map sheets $45\frac{O}{3}$ and $\frac{O}{7}$ (old No. 234) and $45\frac{O}{2}$ and $\frac{O}{6}$ (old No. 233), and chiefly comprising two groups of ridges which may be termed the Jahazpur and Sabalpura hills.

The rocks are quartzites, arkose grits, slates, phyllites and a limestone which is sometimes dolomitic and often cherty. A highly ferruginous quartz-breccia persistently accompanies the limestone at a horizon which is not always quite constant. Its origin has been attributed to solution and collapse under the intense pressure from the north-west which has affected all this region.

The "Jahazpur hills have the great Aravalli gneissic area to their north-west, with intrusions of coarse tourmaline pegmatite, while slates and garnetiferous mica-schists intervene between them and the Sabalpura hills to the south-east. Innumerable intrusions of white reef-quartz are a feature of this zone, being probably the ultimate phase of the pegmatite. There are also rare dykes of coarse amphibolite.

In the Sabalpura hills, the rocks are similar to those of the Jahazpur hills. The central portion of the former is occupied by two separated areas of the dark Aravalli gneissic granite, upon which rest, with a clear erosion unconformity marked by a conglomerate layer at their base, arkose grits succeeded upwards by the quartzites. There are a few bosses of aplite, some rare basic dykes, and abundant injections of pegmatite and white reef-quartz in the gneissic granite.

South-east of the Sabalpura hills lie the rocks of the Gwalior system, consisting mostly of shales, slates, and graywacke. Again there are abundant intrusions of white reef-quartz.

Beneath the quartzites of the Jahazpur hills, at Jawal, there is a coarse, arkose conglomerate. Similar coarse conglomerates are found elsewhere, but can never be traced for more than a short distance. The unconformity seems to be local, and further evidence will be required before it will be possible to decide whether it corresponds to the great discordance which occurs between the Aravalli and Delhi systems.

Mr Bradshaw remarks that the striking features of the whole area are the steady north-east and south-west strike, and the cleavage dip which is usually steep and to the north-west. It is clear that the original structure has been almost entirely obliterated and that the present is one which has been impressed on all the rocks of the area as a whole by intense stresses from the north-west. There is evidence that the original dips were low and rolling, while the Jahazpur and Sabalpura hills represent isoclines greatly extended in the direction of the general strike. The base of the rocks involved is visible in the unconformable junction with the Aravalli gneissic granite, and possibly in the Jawal unconformity, but their relation to the Gwalior slates and greywackes, and to the Aravalli schists, is at present uncertain.

Bundi and Udaipur States; Rajputana.

Sub-Assistant B. C. Gupta was engaged in mapping the north-western frontier of Bundi and portions of the three districts, Mandalgarh, Chitorgarh and Chhoti Sadri, of the Udaipur State. With a general east-north-easterly strike and persistent north-north-westerly dip the Upper Vindhyan group is represented in the vicinity of Bundi City by the Lower Bhander sandstone, the Samria shales, the Bhander limestone, the Ganurgarh shales, the Upper Rewa sandstone and the Jhiri shales. In the valley W.N.W. of Bundi City the Upper Vindhyans have been folded into a broad anticline with the horizontally-lying Ganurgarh shales at the centre.

The country lying between the Vindhyan belt on the south and the Bundi-Jaipur boundary line on the north is, according to Mr. Gupta, occupied by older rocks, the prevailing types being shales, slates, phyllites, sandstones and limestones, provisionally classed as Aravallis or Gwaliors. True mica-schists and the characteristic Aravalli gneisses, so common in the area further north-west in Ajmer

Merwara, are conspicuously absent here, and lithologically the rocks are more or less reminiscent of the recorded descriptions of the Gwaliors of south-eastern Rajputana.

Work was carried southward along the fault-line marking the junction between the Vindhyans and the Aravallis. In the vicinity of Mandalgarh city, the Vindhyans, represented by their upper members, have been anticlinally folded, the Bhander limestone forming the core and the Lower Bhander sandstone the flanks. Further west and south on approaching Chitorgarh, other members of the Upper Vindhyan series appear. From Basi (25° 1′ : 74° 48′) southward the older members of the Vindhyan system begin to appear, and below the Kaimur quartzite the Suket shales, the Nimbahera limestone and the 'purple' shales appear successively in folds with north-and-south axes and low dips.

On the north and west of the boundary fault in the Mandalgarh and Chitor districts Mr. Gupta notes that the ancient shales, etc., have been intruded by granites and dolerites as well as by the pegmatitic quartz. In the south the eastern portion of the Chhoti Sadri area has been greatly covered by the Deccan-Trap lava flows; the country between Neemuch and Chhoti Sadri contains a number of flat-topped trap hills and plateaux, besides innumerable patches of laterite.

Simla Hill States.

During the spring of this year work was continued by Mr. W. D. West under the guidance of Dr. G. E. Pilgrim in the Central Himalayan regions, starting in the Simla Hill States. After a preliminary examination of the rocks at Solon and Simla, and between these two places along the cart road, a traverse was made from Solon to Chakrata along the south side of the Chor mountain.

In many ways the conclusions reached differ fundamentally from those held in the past by Medlicott and R. D. Oldham. In particular the correlation of the rocks above the Blaini at Simla and Jutogh with the Krol and Infra-Krol of the type area is doubted. These Simla rocks, highly metamorphosed in places, are regarded by Dr. Pilgrim and Mr. West as much older than the Krol and Blaini, and as having been brought into their present position above the latter rocks by at least one recumbent fold, accompanied by over-thrusting.

Near Dudham (30° 53′ : 77° 17′), on the north side of the Giri River, is a section similar in structure to that seen at Simla. On

the south side of the Giri is the normal sequence of Infra-Blaini overlain by Blaini, Infra-Krol and Krol. But on the north side the Infra-Blaini and Blaini are overlain by a series of quartzites, crushed purple conglomerates, and schists (Jagas beds), evidently much older. We here have a structure very similar to that seen at Simla; and the fact that the normal sequence is seen so near by is additional evidence for regarding the beds above the Blaini as out of place. Their greater age is suggested from their metamorphosed nature, and they are thought perhaps to be correlated with R. D. Oldham's Jaunsar beds. In the Pervi Nala just north of this spot the Blaini beds have been seen lying unconformably upon these beds.

A still older series of rocks quartzites, slates, carbonaceous slates and black limestone—evidently corresponding to Oldham's 'Carbonaceous series,' and perhaps including the Jutogh Limestone, seem to have been thrust over the Jagas beds, and are themselves repeated by much folding. Later work indicated that part at least of Oldham's Chakrata limestone is of the same horizon. Between Haripur and Geruani, on the south-eastern spur of the Chor, a big recumbent fold of these beds was seen, and interpreted as a syncline opening to the south.

On approaching the Chor granite the increase of metamorphism is at once evident. It is, however, essentially of a regional type, and it is thought that the extra heat available, superimposed upon the regional stresses, was responsible for the higher grade of metamorphism. The change is marked by the incoming of the minerals muscovite, biotite, garnet and staurolite, in that order on approaching the granite, though biotite is not always prominent. The sillimanite zone is never reached. The rocks are at first highly schistose, and in the higher grades are coarse gneisses. In certain beds, the carbonaceous slates, porphyroblasts of ottrelite, or of a mineral closely allied to it, are developed; this mineral comes in before garnet, but is also present in the garnet zone.

The intrusion of the Chor granite is thus regarded by Mr. West as contemporaneous with the movements that produced the folding and the cleavage of the rocks, and this is supported by the fact that the granite is itself often highly foliated. This age must be at least pre-Blaini, for the latter rocks have been brought up by thrusting within the metamorphic aureole, but are themselves unmetamorphosed; microscopic evidence confirms this view.

Further east, near and in the Tons river, is a set of beds which are evidently younger than the Jaunsars, but beneath which they are now seen; they are possibly Infra-Blaini. In the Chakrata district itself sufficient work was not done to justify any definite conclusions. The beds by Chakrata and Kailana however appear to be of the supposed Infra-Blaini type as seen in the Tons. It is also thought that there are at least two limestones of quite different ages, which have hitherto been mapped as one in the Jaunsar rocks.

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THE ZONAL DISTRIBUTION AND DESCRIPTION OF THE LARGER FORAMINIFERA OF THE MIDDLE AND LOWER KIRTHAR SERIES (MIDDLE EOCENE) OF PARTS OF WESTERN INDIA. BY W. L. F. NUTTALL, D.F.C., M.A., F.G.S., SEDGWICK MUSEUM, Cambridge. (with Plates 1—8.).

(1) INTRODUCTION.

The following article includes a very brief account of the stratigraphy of the Lower and Middle Kirthar (Middle Eocene) strata of parts of Western India, and a detailed description of the commoner and larger *Foraminifera* found in these beds. The specimens were collected by Mr. D. Dale Condit and the writer during a geological reconnaissance undertaken on behalf of the Whitehall Petroleum Corporation during the winters of 1920-21 and 1923-24. The writer and editor are indebted to the Directors of the Corporation for permitting the publication of this article. Thanks are also due to Professors M. Boule and H. Douvillé for kindly giving the writer every facility to examine D'Archiac's types from India and other specimens in the Paris Museums. Dr. W. D. Lang found Sowerby's type specimens from Cutch and was kind enough to lend other material for comparison from the British Museum (Natural History). The figured specimens and types of new species are deposited in the Sedgwick Museum, Cambridge. The bibliographical references will be found at the end of the paper. In the palæontological portion the synonymic lists are incomplete, the references most useful for identification being given.

(2) THE STRATIGRAPHY OF THE KIRTHAR SERIES.

The Kirthar series consists of massive white Nummulitic limestones and olive to gray shales, which occur throughout parts of Cutch (Kachh), Sind, Baluchistan and the Punjab in Western India. Lithologically they are similar to the rocks of the Laki series, which in some areas underlie them conformably, and are distinguished by containing a different fauna of *Foraminifera*, which I have described

recently elsewhere (48). The regions in which the Kirthar series crop out have been examined chiefly by Wynne, Griesbach, Blanford, Oldham and Vredenburg, and the geology is described in Memoirs and Records of the Geological Survey of India. (67, 30, 3, 4, 49, 50, 65, 66). In this article it is not proposed to give a lengthy account of the stratigraphy of the Kirthar series, other than that which is necessary to show the vertical distribution of the larger *Foraminifera.*

The Kirthar series has been divided into three main groups the Upper, Middle and Lower, and Vredenburg during his extensive geological reconnaissances in Western India located where these groups crop out (65, 66). In 1906 he published a table showing the vertical distribution of the Indian *Nummulites* (63c). He mentioned several species (see p. 126) the identification of some of which is uncertain and since he has not described any of the forms which he recorded, his table is of relatively little value for determining the different stratigraphical horizons. In this table he divided the Middle Kirthar into A and B, as well as the Upper Kirthar into 1, 2, 3 and 4, without giving any exact explanation as to what these sub-divisions represent. A partial revision of his conclusions appeared in 1912 (20). He classified as Upper Kirthar the massive limestones of the Kirthar Range and the lower Mula Valley, and incorporated in this division 2,000 feet of strata which I have not examined. The knowledge of the fauna contained in these beds is very incomplete. In the area that I have visited I have been able to recognize by a study of the faunas the following groups which are lithologically indistinguishable :—(A) Upper part of the Middle Kirthar, (B) Lower part of the Middle Kirthar, (C) Lower Kirthar. These will be described separately below.

(A) Upper Part of the Middle Kirthar.

I have collected specimens of *Foraminifera* from about 300 to 400 feet of limestones and shales of the upper part of the Middle Kirthar. These beds crop out in the hill range south-east of Damach, Thano Bula Khan *taluqa*, Karachi district, in the Laki Range west of Laki village and in the hills south of Rohri, Sind. Near Damach and in the Laki Range the upper part of the Middle Kirthar rests unconformably on the Laki Limestone of the Laki series (Lower Eocene) and is overlain unconformably by the Nari series (Oligocene). In these areas the lower part of the Middle Kirthar and Lower

Kirthar are absent. In the hills south of Rohri the stratigraphical relations of the beds exposed are not shown, as the Middle Kirthar crops out of the Indus River alluvium.

The fauna is different from that of the lower part of the Middle Kirthar and the *Foraminifera* that I have found in these beds are *Nummulites carteri*, *N. gizehensis*, *N. lævigatus*, *N. aff. scaber*, *Assilina cancellata*, sp. nov.. *A. papillata*, sp. nov., *A. spira*, *Alveolina elliptica*. and *Discocyclina sowerbyi*, nom. nov.

(B) The Lower Part of the Middle Kirthar.

The areas in which I have examined outcrops of the lower part of the Middle Kirthar are the Dera Ghazi Khan district of the Punjab, the Loralai district, the Bugti Hills, parts of Kalat and Las Bela States of Baluchistan and Cutch (Kachh). The rocks consist of not more than 1,300 feet of massive white limestones and shales containing abundant *Foraminifera*. The group is characterized by containing many *Discocyclina*, the fauna collected from these beds being :—*Nummulites acutus*, *N. atacicus*, *N. beaumonti*, *N. lævigatus*, *N. maculatus*, sp. nov., *N. obtusus*, *N. stamineus*, sp. nov., *Assilina exponens*, *Dictyoconoides cooki*, *Discocyclina dispansa*, *D. sowerbyi*, nom. nov., *D. javana* var *indica*, nov., *Actinocyclina alticostata*, sp. nov. and *Alveolina elliptica*.

In most localities the Middle Kirthar (B) has a higher percentage of shale than the Lower Kirthar, but generally the groups are lithologically indistinguishable. The line demarcating the lower limit of the former is entirely artificial, as the rocks pass down conformably into the latter.

In all the areas mentioned above the lower part of the Middle Kirthar is overlain unconformably by Miocene or Oligocene beds, as described later. At no point have I examined a section in which the lower part of the Middle Kirthar passes up conformably into the upper. The marked differences in the faunas between the two groups indicate a non-sequence at the top of the lower part of the Middle Kirthar. The only species of *Foraminifera* that I have observed to be common to the two are *Nummulites obtusus*, *N. lævigatus*, *Alveolina elliptica* and *Discocyclina sowerbyi*, nom. nov.

Previous to the deposition of the Oligocene the Eocene beds of the Bugti Hills, Loralai and Dera Ghazi Khan districts were elevated,

subjected to subaerial denudation, and the upper part of the Middle Kirthar as well as the Upper Kirthar removed.

The Middle Kirthar (B) is well exposed on the flanks of foot-hills of the Sulaiman Range extending from a point north of Fort Munro in the Punjab for about 40 miles to Drug in Baluchistan. In this area the generalized section is as follows:—

	Thickness in feet.
PLEISTOCENE AND PLIOCENE. Upper Siwalik conglomerates, underlain by Lower Siwalik sandstones and shales, .	about 10,000
MIOCENE. Gaj. Ferruginous sandstones and pebble beds,	about 1,000
(The contact of the Gaj with the underlying Kirthar is unconformable).	
EOCENE.	
Lower part of the Middle Kirthar.	
Brown to blue shales with much secondary gypsum. Near the base are several calcareous bands almost entirely made up of *Discocyclina undulata* sp. nov. *D. Sowerbyi*, nom. nov. and *D. javana* var *indica* nov., which beds form an horizon that can be traced for many miles. In places these rocks also contain *Nummulites atacicus*	1,200
A persistent bed of pure white limestone, forming a prominent strike ridge, which can be traced for over 30 miles. This limestone is very fossiliferous, the lower part containing abundant *Discocyclina dispansa*, also *D. sowerbyi*, *Nummulites beaumonti*, *N. acutus* and *Dictyoconoides cooki*	20 to 30
Lower Kirthar.	
Blue grey shales weathering olive green with much secondary gypsum in the form of clear selenite crystals. Near the top is a brown sandy limestone crowded with *Ostræa*	900
Limestone with grey to black chert bands	40
Persistent bed of massive white amorphous gypsum	15
Blue-grey shales	400
Massive white limestone with *Nummulites atacicus*	1,300
Laki series. Ghazij Shales.	
Blue-grey fissile shales with thin limestone bands in the upper part, containing *Nummulites atacicus* and *Assilina granulosa* .	about 2,000
Dunghan Limestone.	
Conglomeratic hard dark limestone interbedded with olive shales, containing *Alveolinæ*, resting unconformably on Cretaceous Pab Sandstone, ... about	500
Total thickness of Eocene rocks measured .	6,385

The following is the section of the Kirthar beds on the south flank of the Pir Karoh Range, Bugti Hills, Baluchistan, where there is less shale than in the section further north described above :—

MIOCENE. Gaj sandstones and shales with mammalian and other bones.

OLIGOCENE. Nari. Very ferruginous calcareous sandstone, in some localities glauconitic, containing *Nummulites intermedius* and *Pecten* sp. This bed marks an unconformable contact at the top of the Kirthar series.

EOCENE.

Lower part of the Middle Kirthar.

Nodular white unfossiliferous limestone	75
Olive shales	300
Intercalated limestones and shales with *Discocyclina javana* var. *indica* nov., at base	200
Nodular and massive white limestone with *Nummulites stamineus* sp. nov.	325
Massive unfossiliferous limestone with chert bands	250
White nodular limestone with *Nummulites beaumonti*, *Discocyclina javana* var. *indica* nov., *Dictyoconoides cooki*, and *Alveolina elliptica*	60
Chocolate, olive or greenish shales with *Alveolina elliptica*	70

Lower Kirthar.

Massive limestone with some intercalated gypseous and shaly beds, with *Nummulites obtusus*. Base not seen	700
Total thickness of Kirthar beds measured	1.980

In Cutch the lower part of the Middle Kirthar consists of about 500 feet of well-bedded white limestones, overlain unconformably by about 10 feet of Nari Limestone with *Nummulites intermedius* and *N. clipeus* (46), and at its base about 75 feet of shales which rest unconformably on a laterite at the top of the Deccan Trap (67). The *Foraminifera* that occur in the limestone are *Nummulites acutus*, *N. maculatus* sp. nov., *N. stamineus* sp. nov., *N. obtusus*, *Assilina exponens*, *Alveolina elliptica*, *Discocyclina dispansa*, *D. sowerbyi* nom. nov., *D. javana* var. *indica* nov., *Actinocyclina alticostata* sp. nov., and *Dictyoconoides cooki*.

(C) The Lower Kirthar.

I have examined the Lower Kirthar rocks in the Dera Ghazi Khan district of the Punjab, and in the Loralai district, Bugti Hills and

Bolan Pass of Baluchistan, where they consists of about 1,500 to 2,500 feet of massive, white, rather unfossiliferous limestones intercalated locally with shales and occasional sandy or gypseous beds. They rest conformably on the Ghazij Shales and there is no sharp line separating the latter from the Lower Kirthar. In the upper part of the Ghazij Shales are thin limestones crowded with *Assilina granulosa*, and also containing *Nummulites atacicus* as a common fossil. I have collected the following *Foraminifera* from the Lower Kirthar: *Nummulites atacicus*, *N. obtusus* and *Assilina exponens*.

In the palæontological portion of this paper the above species of *Foraminifera* are described, and in each case a list of the localities is given stating where the specimens were collected. The following table giving the stratigraphical distribution of the *Foraminifera* of the Middle and Lower Kirthar is provisional. It is based solely on the above occurrences, the microspheric form only being quoted. If careful collecting were undertaken over a larger area other species would be found and it is also not improbable that slight alterations would have to be made in the vertical distribution of some of the species mentioned below. It is clear, however, that the three divisions in the Kirthar series given below can be distinguished by their containing characteristic faunas of *Foraminifera*.

(3) TABLE SHOWING THE STRATIGRAPHICAL DISTRIBUTION OF FORAMINIFERA IN THE LOWER AND MIDDLE KIRTHAR SERIES.

Genus and Species.	Laki series.	KIRTHAR SERIES.		
		Lower Kirthar. (C)	Lower part of Middle Kirthar (B).	Upper part of Middle Kirthar (A).
Nummulites atacicus, Leym.	——	——	——	
Assilina exponens, (Sow.)	——	——	——	
Nummulites obtusus, Sow.		——	——	——
Nummulites acutus, Sow.			——	
Nummulites beaumonti, d'Arch. and Haime.			——	

(3) TABLE SHOWING THE STRATIGRAPHICAL DISTRIBUTION OF FORAMINIFERA IN THE LOWER AND MIDDLE KIRTHAR SERIES—*contd.*

Genus and Species.	Laki series.	KIRTHAR SERIES.		
		Lower Kirthar (C).	Lower part of Middle Kirthar (B).	Upper part of Middle Kirthar (A).
Nummulites maculatus, sp. nov.			—	
Nummulites stamineus, sp. nov.			—	
Dictyoconoides cooki, Carter .			—	
Actinocyclina alticostata, sp. nov.			—	
Discocyclina dispansa, (Sow.) .			—	
Discocyclina javana, (Verbeek) var. *indica*, nov.			—	
Discocyclina undulata, sp. nov.			—	
Discocyclina sowerbyi, nom. nov.			—	—
Alveolina elliptica, (Sow.) .			—	—
Nummulites lævigatus, (Brug.)			—	—
Nummulites carteri, d'Arch. and Haime.				—
Nummulites gizehensis, (Forks.)				—
Nummulites aff. *scaber*, Lam.				—
Assilina cancellata, sp. nov .				—
Assilina papillata, sp. nov. .				—
Assilina spira, de Roissy. .				—

(4) THE AGE OF THE MIDDLE AND LOWER KIRTHAR SERIES AS DETERMINED FROM THE LARGER FORAMINIFERA.

The following species of *Nummulites* and *Assilina* that occur in Europe are found in the Middle and Lower Kirthar series of India.

I have only quoted the microspheric forms and have stated the known stratigraphical range of the species in the two regions :—

Genus and Species	Stratigraphical range observed by the writer in India.	Established stratigraphical range in Europe.
Nummulites atacicus	Laki series to lower part of Middle Kirthar.	Lower Eocene to Lutetian. (7i, 21c, 27.)
Nummulites lævigatus	Middle Kirthar	Lutetian (7b, 16, 26, 27).
Nummulites aff. *scaber*	Do.	Do. (7b).
Nummulites obtusus	Lower Kirthar to upper part of Middle Kirthar.	Lutetian to Auversian (7c, 27, 26).
Nummulites gizehensis	Upper part of Middle Kirthar.	Lutetian (7b, 26).
Assilina exponens	Upper part of Ghazij Shales (Laki series) to lower part of Middle Kirthar.	Lutetian (21d, 27) to Auversian (7j).
Assilina spira	Upper part of Middle Kirthar.	Lutetian (7h).

In my recent paper on the Laki series (46) I have classified these beds as Lower Eocene, and the above evidence from the species of Foraminifera indicates that the Lower and Middle Kirthar is equivalent to the Lutetian of Europe.

Throughout the area, the stratigraphy of which I have described briefly above, the lower or upper part of the Middle Kirthar is overlain unconformably by Miocene or Oligocene beds. According to Vredenburg (63d) the massive limestones of the Kirthar Range and the Mula Pass form the Upper Kirthar series. These beds he classified as Upper Lutetian, and according to him beds of Auversian to Priabonian age are absent in Western India. Our knowledge of the foraminiferal fauna of the Upper Kirthar is still very incomplete, so that the age of these beds cannot be determined with any certainty. There is however little doubt that the Lower and Middle Kirthar are equivalent in age to the greater part of the Lutetian of Europe.

With the exception of *Nummulites lævigatus* the stratigraphical distribution of the species mentioned above is approximately the same in India as in Europe. In Europe *N. lævigatus* appears in the Lower Lutetian (21*d* and 26), whereas in India the lowest horizon at which I have observed this species is the lower part of the Middle

Kirthar, probably Middle Lutetian. The mollusca of the Kirthar Series have so far not been the subject of a systematic study. The meagre information regarding this group included in d'Archiac and Haime's monograph (2) throws little light on the age of the beds.

Middle Eocene strata containing among other species *Nummulites acutus* (=*vredenburgi*), *Discocyclina javana* and numerous other Discocyclines have been described in Java, Borneo, the Moluccas, and New Guinea (61, 62, 18, 20, 23). This fauna resembles that of the lower part of the Middle Kirthar of Western India.

(5) PALAEONTOLOGICAL DETAILS.

(A) REVISION OF PREVIOUS DESCRIPTIONS OF NUMMULITES AND OTHER TERTIARY FORAMINIFERA FROM INDIA.

(a) *Sowerby's Description of Tertiary Fossils from Cutch.*

In 1837 J. de C. Sowerby (58, 59) described a collection of fossils from Cutch, which included the following species of Foraminifera from the Middle Kirthar :—

Nummulites (*Nummulina*) *acutus* (see p. 133).
Nummulites (*Nummulina*) *obtusus* (see p. 137).
Assilina (*Nummulina*) *exponens* (see p. 142).
Alveolina (*Fasciolites*) *elliptica* (see Nuttall 47).
Discocyclina (*Lycophris*) *dispansa* (see p. 115).
Discocyclina (*Lycophris*) *ephippium* (see p. 14[illegible]).

I have collected specimens of all these species from Cutch and have re-described them giving details of the internal structure, which were for the most part omitted by Sowerby. Sowerby's types of each of these species, except that of *D. dispansa*, are preserved in the British Museum (Natural History).

(b) *The Monograph on Nummulites by Messrs. D'Archiac and Haime.*

D'Archiac and Haime in their classical monograph of 1853 on the genus *Nummulites* recorded from India 18 species of *Nummulites* and *Assilina* which are enumerated below (2a). It is unfortunate that throughout this publication these authors did not state the localities from which their figured specimens of *Nummulites* were collected, as the species are described from widely separated parts of Europe and Asia. In their text when localities in Western India

are mentioned they are usually vague, and most of the specimens from Sind are recorded as having been found in the Chaine D'Hala, which as a range of hills is purely a geographer's myth. By the Chaine D'Hala D'Archiac appears to have meant parts of the Kirthar Range and any of the hill ranges of Lower Sind. Also when the specimens described from India by D'Archiac were collected little was known of the geological succession of the Tertiary rocks, and in consequence no effort was made to separate the species according to their stratigraphical horizons. These factors deduct much from the value of their work.

In 1903 Thévenin (60) by making a careful examination of D' Archiac's collection and by comparing the specimens with the figures was able to find a number of the types and determine which are the figured specimens. Unfortunately certain specimens were inadequately labelled and others lost so that our information in this respect is incomplete. In the list below I have marked with an asterisk five species of *Nummulites* from India of which the original types or figured specimens are still preserved in the *Musée de Paléontologie* at Paris, and have discussed separately each species recorded from India by D'Archiac :—

Nummulites lyelli, A. and H. According to Thévenin D'Archiac's Plate II, figs. 10, 10a, 10b, var. b, is doubtfully ascribed to specimens of this species from Sind. Boussac (7a) and other recent writers classify this species as synonymous with *N. gizehensis*, Forsk (see p. 139)

**Nummulites sublævigata*, A. and H. D'Archiac's Plate IV, figs. 8, a to b. This species is synonymous with *N. intermedius*, D'Arch. and occurs in the Oligocene Nari beds (See Nuttall 46).

Nummulites scaber, Lam. D'Archiac and Haime included in this species *N. acutus* of Sowerby, which is different, as described below (p. 133).

**Nummulites obtusus*, Sow. D'Archiac's Plate VI, figs. 13, a to c. The figures and description concord with typical globose forms of the species. Locality, Sind (see p. 137).

**Nummulites lucasana*, Defr. D'Archiac's Plate VII, fig. 10 var. c, from "Subathoo" in the Punjab. The specimen named thus is referred to *N. perforatus*, the megalospheric form of *N. obtusus* (see p. 138).

Nummulites ramondi, Defr. The specimens referred to under this name may be young forms of *N. atacicus* (see p. 129),

Nummulites biarritzensis, D'Arch, partly synonymous with *N. atacicus* (see p. 129).

Nummulites beaumonti, A. and H., described below (p. 130).

**Nummulites vicaryi*, A. and H. D'Archiac's Plate IX, figs. 1, a to b. A nummulite, the septal filaments of which are without granules and very turbulent, which I have not found. Locality, Sind.

Nummulites exponens, Sow. (see *Assilina exponens* p. 142).

Nummulites granulosa, D'Arch. (see *Assilina granulosa*, which is characteristic of the Laki series; see also Nuttall (48a)).

Nummulites spira, de Roissy (see *Assilina spira*, p. 143).

Nummulites garansensis, Joly and Leym. This species is synonymous with *N. fichteli*, Michelotti, the megalospheric form of *N. intermedius* from the Nari Oligocene beds (see Nuttall 46).

**Nummulites carteri*, A. and H. (see p. 139).

Nummulites guettardi, A. and H., probably the same as *N. subatacicus* (see p. 130).

Nummulites leymerei, A. and H. The megalospheric form of *Assilina granulosa*, which occurs in the Laki series (see *Assilina leymerei in* Nuttall (48b)).

Nummulites miscella, A. and H., a *Siderolites* occurring in the Upper Ranikot.

Operculina tattaensis, A. and H., synonymous with *Assilina granulosa* from the Laki series (see Nuttall 48a).

(c) *H. J. Carter's Papers.*

Two important papers on *Faraminifera* in Western India were published by Carter in the years 1853 and 1861 (9 and 10). I have been unable to find Carter's collection of fossils, although in 1900 Chapman mentioned having found and examined part in the British Museum (Natural Histoty) (11). Carter described the following species of *Nummulites* and *Assilina* from India:—

Operculina sp., (1853) pp. 167-168. Pl. VII, figs. 3-4. Equivalent to *Assilina granulosa*, D'Arch. (See Nuttall 48a).

Assilina irregularis, Cart. (1853) p. 168. Pl. VII, figs. 5-6 (1861), p. 366. Equivalent to *Assilina spira*, de Roissy (see p. 143).

Assilina sp. (1853), pp. 168-169. Pl. VII, figs. 7 to 8 (1861), pp. 367-368. Pl. XV, figs. 1, a, b and c. Equivalent to *Assilina exponens* (see p. 142).

Nummulina sp.? (1853) p. 169. Pl. VII, figs. 9-10 (1861), pp. 369-370. Equivalent to *Nummulites carteri*, D'Arch. & H. (see p. 139).

Nummulina obtusa, Sow. (1853) p. 170, Pl. VII, figs. 13-14 (1861), pp. 371-373. (see p. 137).

Nummulina acuta ? Sow. (1853), p. 171. Pl. VII, figs. 21-22 (1861), pp. 376-378. Equivalent to *Nummulites intermedius*, D'Arch., of the Oligocene Nari beds (see Nuttall 46).

Assilina obesa, Cart. (1861), p. 368. Pl. XV, figs. 2 a, b, c and d. Equivalent to *Assilina mamillata*, (D'Arch.) (see p. 143.)

Nummulites broachensis, Cart. (1861), p. 373, Pl. XV, figs. 3, a to e. I have not found this species.

Nummulites biarritzensis, A. and H. (1861), pp. 373-374. Probably *N. atacicus* or *N. stamineus* (see pp. 129, 131).

Nummulites ramondi, Defr. (1861), pp. 374-375. Probably young *N. atacicus* (see p. 129).

Nummulites ke'atensis, Cart. (1861), p. 376, Pl. XV, fig. 6, a to d. I have not found this species.

Nummulites irregularis; Desh. (1861), p. 376. (see Nuttall (48)) This species I have found in the Laki series.

In addition to the above Carter also figured and described Kirthar species of *Discocyclina* (see p. 145), as well as numerous Eocene *Alveolinae* (see Nuttall 47 and 48c) and *Dictyoconoides cooki*, (Cart.) (see Nuttall 47).

(*d*) *Articles by E. W. Vredenburg and G. de P. Cotter.*

In 1906 Vredenburg (63a and b) described as a new species *Nummulites douvillei* (=*vredenburgi*, auctorum) from Cutch, which species for reasons given below (p. 133) I regard as synonomous with *N. acutus*, Sowerby. In the same article he gave a table showing the zonal distribution of Indian *Nummulites*. As stated above he has not described any of the species mentioned, and some of the identifications are uncertain. The species which he records as occurring in the Lower and Middle Kirthar are as follows :—*Nummulites perforatus* (which is synonomous with *N. obtusus*, see p. 137), *Assilina spira* (see p. 143), *Nummulites beaumonti* (see p. 130), *Nummulites murchisoni* (I have not observed this species in India), *N. discorbina* (I have not observed this species in India ; a closely related form is *N. stamineus*, sp. nov., see p. 131), *N. lævigatus*, (see p. 134), *Assilina exponens* (see p. 142), *A. sufflata*, Vred.—a

species which was not described, said to be related to *A. spira*, possibly *A. papillata*, nov. (see p. 144). *Nummulites douvillei*, Vred. the equivalent of *N. acutus*, Sow., see p. 133), *N. gizehensis* (see p. 139) and *N. irregularis*, which I have only observed in the Laki series (see Nuttall 48d).

In 1914 Cotter (13) described a new species, *Nummulites yawensis*, from Burma, which I have not found in Western India. He also discussed the zonal distribution of Indian *Nummulites*.

LIST OF FORAMINIFERA AND CLASSIFICATION OF NUMMULITES.

It has been well established by Douvillé, Boussac (6, 17, 21, 22, 28a) and others that the only satisfactory classification of the species of the genus *Nummulites* is by the structure of the septal filaments. In many of the specimens found in Europe the structure of the septal filaments is visible on the exterior of the test or is exposed by polishing a surface. In the case of the *Nummulites* from the Kirthar series, in a few instances the septal filaments are visible on the weathered surface of the shell, but usually the state of preservation is such that their structure is not even made clear by means of a polished surface. This is due to the fossil shell consisting of pure white calcium carbonate, and what were originally cavities enclosing the sarcode being filled with transparent colourless or translucent white calcite. In specimens preserved thus the structure of the septal filaments is only made clear by cutting a thin horizontal section of the test, which, if made immediately above the median chamber layer, shows the structure of these filaments from the beginning of the growth of the shell to the adult stage.

In describing the species of *Nummulites* and *Assilina* I have employed the following terms :—

For the "filets cloisonnaires" of French writers the term "septal filaments" is used. These may be "radiate," "reticulate," "meandriform" or as in *Assilina* (see p. 128). The Eocene reticulate Nummulites described have a "simple mesh," which term corresponds to Boussac's "réseau simple." The term "column," employed by Carpenter (8), is used in the same sense as "piliers" of French writers. In certain species the columns where they come to the outer surface of the shell form protruberances known as "granules" (see Plate II figs. 2 and 3).

An "axial" section is cut at right angles across the shell perpendicular to the plane of symmetry, as in Plate II, figure 5. An "equatorial" section is cut through the plane of symmetry showing the median chamber layer as in Plate I, figure 6. In an equatorial section there are the chambers, the septa, the whorl laminæ; the width of the chambers is measured parallel to the radius, the length parallel to the whorl laminæ. A "lateral" section is cut immediately above an equatorial section so as to show the structure of the septal filaments as in Plate I, figure 7. By Form A is meant the megalospheric form, and by Form B the microspheric; these are given separate specific names. Since the microspheric form is the larger it shows best the characteristics of the septal filaments, which are of prime importance in recognizing the couples A and B.

The following classification of the *Nummulites*, based on the structure of the septal filaments, has been adopted, there being however no sharp dividing line between groups 2 and 3 :—

(1) Septal filaments without columns, radiate	(*a*) *N. atacicus*, Leym. (B). *N. subatacicus*, Douv. (A). (*b*) *N. beaumonti*, A. and H. (B). (*c*) *N. stamineus*, sp. nov. (B).
(2) Septal filaments with columns, reticulate with simple mesh . . .	(*a*) *N. acutus*, Sow. (B). *N. djokdjokartæ*, Martin. (A). (*b*) *N. lævigatus* (Brug.) (B). *N. lamarcki*, A. and H. (A). (*c*) *N.* aff. *scaber*, Lam. (B). (*d*) *N. obtusus*, Sow. (B). *N. perforatus*, (de Mont.) (A).
(3) Septal filaments with columns, meandriform	(*a*) *N. carteri*, A. and H. (B). (*b*) *N. gizehensis*, (Forks.) (B). (*c*) *N. maculatus*, sp. nov. (B).
Genus *Assilina*. (Sometimes considered as a subgenus of *Nummulites*) . .	(*a*) *A. concellata*, sp. nov. (B). *A. subcancellata*, sp. nov. (A). (*b*) *A. exponens*, (Sow.) (B). *A. mamillata*, (D'Arch.) (A). (*c*) *A. spira*, de Roissy. (B). (*d*) *A. papillata*, sp. nov. (B). *A. subpapillata*, sp. nov. (A).

The Foraminifera of other genera are :—

Orbitoides.

Discocyclina.

D. dispansa, (*Sow.*)

D. javana, (Verbeek) var. *indica*, nov.

D. sowerbyi, nom. mut.

D. undulata, nov.

Actinocyclina.

A. alticostata, nov.

Alveolina.

A. elliptica, Sow. (see Nuttall 48).

Dictyoconoides.

D. cooki, (Carter.) (see Nuttall 48).

In the case of the *Orbitoides* the terms axial and equatorial sections are employed in the same sense as with *Nummulites*. A "lateral" section is cut horizontally a very short distance above the upper surface, so as to show the adult development of the columns of shell substance in the lateral chamber layer.

(C) Description of the species of Kirthar Nummulites, Assilinae and Orbitoides.

Genus, NUMMULITES, Lamarck.

(I) Nummulites with radiate septal filaments without columns.

NUMMULITES ATACICUS, Leymerie.

1844. *Nummulites atacicus*, Leymerie. (39).
1925. *Nummulites atacicus*, Leym. Nuttall (48c) cum syn.

In a recent paper I have figured and described *N. atacicus* from the Laki series of India. The representatives of the species as found in the Kirthar beds are characterized by having sinuous septal filaments, as in Plate XXV, figures 1 and 2 of the above paper. This species which is found throughout the Laki series, ranges up into the lower part of the Middle Kirthar. I have examined numerous specimens from the following localities:—

(*a*) From the Middle Kirthar (B), about 2 500 feet above the contact of the Lower Kirthar with the Ghazij Shales, Garmaf hot spring, Buzdar tribal tract, Dera Ghazi Khan foothills, S. W. Punjab. A large variety, its average diameter 23·5 mm., maximum observed diameter

28·8 mm., average thickness 5·8 mm., maximum thickness 6·7 mm. Average ratio of diameter to thickness, 4 to 1. There are 9 whorls in the first 3 mm. of radius and 16 in a radius of 9 mm.

(*b*) From the shales of the Middle Kirthar (B); N. E. of Pabuni Chauki, Las Bela State, Baluchistan. Average diameter 12·1 mm., average thickness 5·3 mm. Average ratio of diameter to thickness 2·3 to 1.

(*c*) From the shales of the Middle Kirthar (B), west of the Hab River, west of Khand Jhand, Karachi district, Sind. Similar to b.

(*d*) From the top of the Lower Kirthar; 6 miles N. E. of Rarisham, Loralai district, Baluchistan. Average diameter 14·9 mm., maximum observed diameter 16·3 mm., average thickness 4·8 mm., maximum thickness 5·2 mm. Ratio of diameter to thickness 3 to 1.

NUMMULITES SUBATACICUS, Douvillé.

1919. *Nummulites subataricus*, Douvillé (21a).
1925. *Nummulites subatacicus*, Douvillé, Nuttall (48f)

This species, which is the megalospheric form of *N. atacicus* has been found associated with it at locality (*b*) above and was observed in the same beds west of Pabuni Chauki. Average diameter 5·5 mm., maximum diameter 6·9 mm, average thickness 3·3 mm, maximum thickness 4·0 mm. Average ratio of diameter to thickness 1·7 to 1. There are 7 whorls in a radius of 2·5 mm., and 8 in a radius of 3 mm. The septal filaments are nearly straight radiate.

NUMMULITES BEAUMONTI, D'Archiac and Haime.

1853. *Nummulites beaumonti*, D'Archiac and Haime. (2b).
1883. *Nummulites beaumonti*, D'Archiac and Harpe. (33b).
1902. *Hantkenia beaumonti*, A. and H. Prever. (51).

Plate I, figs. 4 and 5.

This species was recorded by D'Archiac and Haime from Subathu ("Subathoo") in the Punjab, Cherrapunji ("Cherra Poonji") and near Sylhet ("Silhet") in Assam, but the types from India are no longer preserved. Writing of this species from Egypt in 1877

de la Harpe states (32):—"J'ai pu me convaincre par l'examen d'une riche moisson de *N. Beaumonti* rapportée d'Egypte par M. le professeur Zittel, que cette dernière espèce n'est qu'une variété de la *N. Biarritzensis.* D'après D'Archiac la différence essentielle entre elles consisterait dans la spire plus fine et plus serrée de la *N. Beaumonti.*" In 1883 de la Harpe classified *N. beaumonti* as a definite species. Where I have found *N. beaumonti* in the Middle Kirthar (B) I have had no difficulty in distinguishing it from the closely related species *N. atacicus* (=*biarritzensis*), which, as stated above, has a much wider stratigraphical range. I have not found the megalospheric form.

The specimens of *N. beaumonti* that I have examined have slender, nearly straight to slightly curved, radiate septal filaments, which are shown clearly in Plate I, figure 5. In equatorial section (fig. 5) the whorls are seen to be close together, very regular, and the septa practically straight, which distinguishes the species from young specimens of *N. atacicus*. The average diameter of the shell is 6·8 mm , the maximum observed diameter being 7·5 mm. Average thickness 3·6 mm., maximum observed thickness 4·4 mm., average ratio of diameter to thickness 1·9 to 1. There are 13 whorls in a radius of 3 mm.

In one quadrant of the 5th whorl there are 8 septa.
In one quadrant of the 6th whorl there are 11 septa.
In one quadrant of the 7th whorl there are 11-12 septa.
In one quadrant of the 8th whorl there are 13 septa.
In one quadrant of the 9th whorl there are 15 septa.

Occurrence:—Horizon, Middle Kirthar (B). (*a*) From about 2,500 feet above the contact of the Lower Kirthar with the Ghazij Shales; Dawagar, Dera Ghazi Khan foothills, S. W. Punjab (very common), (*b*) From the same horizon, Drug, Loralai district, Baluchistan. (*c*) From 5 miles N. of Dera Bugti, Bugti Hills, Baluchistan. (*d*) From Taghoa, Loralai district, Baluchistan (common). This species occurs in the Middle Eocene of Egypt and is recorded from Italy, the horizon in this case being uncertain but probably Lutetian.

NUMMULITES STAMINEUS, sp. nov.

Plate I, figs. 1-3.

Test lenticular, border bevelled, average diameter 14·7 mm., largest diameter observed 20·4 mm., average thickness 5 mm.,

maximum thickness observed 8·3 mm. Average ratio of diameter to thickness 3 to 1. Septal filaments fine, simple, radiate, gently curved, somewhat irregular. In equatorial section (Plate I, fig. 3) the form is seen to be microspheric, with 9 to 11 whorls in the first 3 mm., 17 to 20 whorls in a radius of 8 mm. Whorl laminæ thick; septa numerous, straight or only slightly curved, set nearly at right angles to the whorl laminæ. Chambers subrectangular in cross-section, their width greater than their length.

In one quadrant	of the	4th	whorl	there are	8—11	septa.
,,	,,	5	,,	,,	10—11	,,
,,	,,	6	,,	,,	11—13	,,
,,	,,	7	,,	,,	11—15	,,
,,	,,	8	,,	,,	12—17	,,
,,	,,	9	,,	,,	13—18	,,
,,	,,	10	,,	,,	15—19	,,
,,	,,	11	,,	,,	17—21	,,
,,	,,	12	,,	,,	17—23	,,

This nummulite resembles several known species, but is different from any of the described Eocene forms. *Nummulites* probably belonging to this species from Lakpat ("Lukput") in Cutch have been referred to *N. atacicus* (=*biarritzensis*) by Carter (10a). Externally some specimens strongly resemble the varieties of *N. atacicus* with fairly straight septal filaments, but internally the whorls are more numerous and the septa set closer together. This species is readily distinguished from *N. kelatensis*, since the fine radiate septal filaments of the latter, as figured by Carter (10b), are more regular and the diameter of the test about half as great as that of *N. stamineus*. A species very closely related is *N. discorbinus*, Schloth. (see Harpe 33a), which is primarily distinguished by being smaller and much more globose.

Occurrence:—Stratigraphical horizon, Middle Kirthar (B). (*a*) From 1 mile south of Waghapadar ("Waggerpudder"), Cutch. (*b*) From 2 miles S. W. of Godhathad (Gothahad), Cutch. (*c*) From the massive Kirthar limestone, 600 feet below the contact with the Nari series; Kalu Kushtak Nala, due N. of Lakhe-ka-kot, Bugti Hills, Baluchistan (common).

(II) Nummulites with reticulate septal filaments of simple mesh and with columns.

NUMMULITES ACUTUS, Sowerby.

1837 (1840) *Nummularia acuta*, Sowerby (58a).
1906. *Nummulites douvillei*, Vredenburg (63a) Form B.
1908. *Nummulites vredenburgi*, Prever in Vredenburg (64).
1912. *Nummulites vredenburgi*, Douvillé (19a) cum syn.
1923. *Nummulites vredenburgi* Douvillé (23).

Plate II, figs. 1-4.

Vredenburg described this species as *N. douvillei* from Lakhpat and Noondatur in Cutch, but there are a few important characteristics which he has not made clear. He has only figured adult specimens of the microspheric form, and, to judge from his remarks on page 85, he has referred young specimens to *N. scaber*, Lam., which externally they resemble. D'Archiac and Haime (2e) have incorrectly placed *N. acutus* as synonymous with *N. scaber*, the Indian representative of which species is described below.

In Vredenburg's description of the exterior of *N. douvillei* he omitted to state that in the adults a small central mamelon is not uncommonly found; I have found it in about 10 per cent. of the specimens of this species in my collection from Cutch. Also where the exterior layer of shell substance has not been removed by weathering, sinuate radiate ridges may be seen on the outer surface (See Plate II, fig. 1). Strong granulations are found in young forms and are well shown in figures 2 and 3. Of the nummulites referred to *N. acutus* by Sowerby from Lakhpat in Cutch, one of the types (the top, right, figured specimen) is preserved in the British Museum (Natural History); Dr. W. D. Lang kindly arranged to have it photographed (fig. 3). This is clearly a young granular form of the species, the exterior appearance of which is identical with that of another young specimen in my collection (fig. 2), which is better preserved than the type. In the case of the remainder of Sowerby's figured specimens it is doubtful to what species they belong, and it seems that the specimens are lost.

The structure of the septal filaments is characteristic of the species and is identical in young granular forms and in the adult smoother varieties. It is only diagrammatically represented in

Vredenburg's figure 8b. Where the upper layer of shell substance is weathered away the septal filaments are partially exposed and appear exactly like those shown in Douvillé's excellent photographs of specimens from Java (19a). The septal filaments are best seen by making a thin lateral section of the shell immediately above the median chamber layer (as in fig. 4), which shows that they are indistinguishable from those of a specimen figured by Douvillé from Roti Island (23). The specimens from near Godhathad ("Gothahad") are of approximately the same size as those described by Vredenburg, the diameter varying from 17·9 to 9·7 mm., the thickness from 4·9 to 3·3 mm., and for twenty specimens the average ratio of diameter to thickness being 3·7 to 1.

This species, which in India has been recorded from Cutch and Burma (13), is also found in Baluchistan, the localities from which I have examined specimens being as follows :—Stratigraphical horizon, Middle Kirthar (B). (*a*) From the base of the Kirthar Limestone; 2 miles S. W. of Gothahad (Godhathad), Cutch (common). (*b*) From 1 mile south and 1½ miles N. of Waghapadar (Waggerpudder), Cutch. (*c*) From a bed of white limestone, 20 feet in thickness, at about 2,600 feet above the contact of the Lower Kirthar Limestone with the Ghazij Shales, E. of Drug, Northern Baluchistan.

NUMMULITES DJOKDJOKARTÆ, Marti.

1881 *Nummulina djokdjokartæ*, Martin (41).
1906. *Nummulites Douvillei*, Vredenburg (63b). Form A.
1912. *Nummulites djokdjokartæ*, Martin, Douvillé (19b) cum syn.

This species, which is the megalospheric form of *N. acutus*, has been described by Vredenburg from Cutch.

NUMMULITES LÆVIGATUS, (Bruguière, sp.)

1792. *Camerina lævigata*, Bruguière (5).
1853. *Nummulites lævigata*, (Brug.) D'Arch. and Haime (2c).
1902. *Nummulites lævigatus* (Brug.), Douvillé (17).
1905. *Nummulites lævigatus* (Brug.), Lister (40a).
1906. *Nummulites lævigatus* (Brug.), Boussac. (6).
1911. *Numulites lævigatus* (Brug.), Boussac. Form B (7b).
1915. *Nummulites lævigatus* (Brug,) Dainelli (15a)

Plate I, figs. 6-7.

This species is very abundant at Sukkur, Sind. The average diameter of the test ot specimens from this locality is 23·2 mm., the maximum diameter observed being 35·4 mm. The average thickness is 4·2 mm., the maximum thickness observed being 5·4 mm. The average ratio of diameter to thickness is 1 to 5·5. The test is flat, lenticular, with a rounded border. Externally the state of preservation is such that it is not possible to make out any of the structure of the septal filaments, the details of which are shown in a lateral section (Plate I, fig. 7), in which case the forms appear to be identical with European representatives of the species.

The septal filaments may be distinguished from other related species from India by their thickness being variable and the shape of the columns irregular. In *N. acutus* the filaments are thicker and less meandriform. In the Indian representatives of a form allied to *N. scaber* the septal filaments are more widely spaced and the columns not infrequently larger than in *N. lævigatus*. In the varieties of *N. obtusus* the filaments are fine, very turbulent, with well rounded columns. These species are also distinguished by other characteristics mentioned below in the description of each. In an equatorial section of *N. lævigatus* there are 17 whorls in a radius of 10 mm.; the structure of the median chamber layer is shown in Plate I, figure 6.

Occurrence:—(*a*) From the lower part of the Middle Kirthar; west of Pabuni Chauki, Las Bela State, Baluchistan (rare). (*b*) From the upper part of the Middle Kirthar; Sukkur, Sind (very abundant).

NUMMULITES LAMARCKI, D'Archiac and Haime.

1853. *Nummulites lamarcki*, A. and H. (2d).
1905. *Nummulites lamarcki*, A. and Lister (40b).
1911. *Nummulites lævigatus*, Brug, Boussac, Form A. (7c).

This species, which is the megalospheric form of *N. lævigatus*, occurs in abundance associated with it. The diameter of the test varies from 5 to 8 mm. and the average thickness is 2·5 mm. The structure of the septal filaments is identical with that of *N. lævigatus*. In equatorial section the diameter of the megalosphere attains 1 mm. and in a radius of 4 mm. there are 5 whorls.

NUMMULITES aff. SCABER, Lamarck.

1804. *Nummulites scabra*, Lamarck (38).
1853. *Nummulites scabra*, Lamarck D'Archiac and Haime (2f).
1863. *Nummulites scaber*, Lam. Schafhautl. (53*a*).
1918. *Nummulites scabra*, Lam. Favre. Lamarck's types (28).

Plate II, figs. 5-8.

There appears to be no recent description of this species. In 1911 Boussac (7d) classified it as a granular variety of *N. lævigatus*, and since then photographs of Lamarck's original types of *N. scaber* have been published. It is clear from one of these (see (28), fig. 38a) that the structure of the septal filaments is different from that of a typical *N. lævigatus* and is I think sufficiently distinct to warrant distinguishing the form as a separate, although closely related, species. The filaments are less meandriform, their thickness is less variable and the columns are larger and more circular in shape than in a typical *N. lævigatus*. The diameter of the test also is always smaller and the thickness proportionally greater.

In India there is a closely related form differing somewhat from the European species. Externally the test is smooth, though occasionally ill-defined sinuous lines appear on the surface. The columns, which form prominent granules on the surface of the European specimens, in the Indian forms can only be observed by making thin lateral sections (see figs. 6 and 8). In axial section (fig. 5) the whorls are seen to be set close together and the chambers are much smaller than in Lamarck's type (see (28), fig. 38b).

This fossil is found in the upper part of the Middle Kirthar and is very abundant at Sukkur, Sind. At this locality 80 per cent. of the specimens are very globose with broad rounded border. The average diameter is 12·1 mm. and the average thickness 8·0 mm., the average ratio of diameter to thickness being 1·5 to 1. The globose form is very similar in shape to young *N. obtusus*. The remaining 20 per cent. of the specimens are more depressed, lenticular, with a fairly sharp keeled border. The average diameter is 12·9 mm., average thickness 5·9, and average ratio of diameter to thickness 2·2 to 1. In a radius of 5·5 to 6 mm. there are 16 to 18 whorls, the whorls being closer together near the periphery than in the median portion of the shell. The megalospheric form of this species was not found. The

septa as seen in an equatorial section (fig. 7) are slightly curved and set at an angle usually of about 60° to the whorl laminæ.

In one quadrant of the	3rd whorl	there are	5	septa.
,,	4th	,,	6	,,
,,	5th	,,	5–8	,,
,,	6th	,,	5–8	,,
,,	7th	,,	8–9	,,
,,	8th	,,	8–10	,,
,,	9th	,,	8–10	,,
,,	10th	,,	10–12	,,

Occurrence: Horizon, Middle Kirthar (A). (*a*) From west of Laki village, Sind (common). (*b*) From Jhand Mahomed, Sukkur, Sind. (*c*) From Sukkur, Sind (common). (*d*) From Kubba Shadi Shahid, 4 miles S. E. of Khairpur, Sind.

NUMMULITES OBTUSUS, Sowerby.

1837 (1840) *Nummularia obtusa*, Sowerby (58b).
1848. *Nummulites aturicus*, Joly and Leymerie (35).
1853. *Nummulina obtusa*, Sow., Carter (9a).
1853. *Nummulites obtusa*, Sow., D'Archiac and Haime (2g).
1861. *Nummulites obtusa*, Sow., Carter (10c).
1911. *Nummulites perforatus*, D. de Mont., Boussac. Form B. cum syn. (7e).
1915. *Nummulites obtusus*, Sow., Dainelli (15b).

Plate II, fig. 10. Pl. III, figs. 1-2.

Indian representatives of this species have been well described and figured by Carter, D'Archiac and Haime. Sowerby's type from Cutch is preserved in the British Museum (Natural History) and D'Archiac's specimens in the Musée de Paléontologie, Paris. I have only obtained one specimen of this species from Cutch, where it is rare, but have found it abundantly in parts of Sind and Baluchistan, its stratigraphical range extending from the base of the Lower to the upper part of the Middle Kirthar. The type of the Indian species is very globose with many close-set whorls, this form being common. Much flatter lenticular forms are also found, similar to varieties in Europe. For the typical globose variety the diameter varies from 15 to 20 mm., and the thickness from 6 to 11 mm. In the case of the lenticular varieties, which are found in different localities (c,b and g) from those in which the globose are found

(a, d, e and f), the diameter varies from 12 to 19 mm., and the thickness from 4 to 7 mm. In the more globose forms the border is rounded and in the flatter forms keeled. The meandriform structure of the septal filaments is fairly constant, the number and size of the columns being variable. In all cases where a lateral section is obtained a short distance above the median chamber layer, it was observed that in the earlier stages of growth columns are always present, whereas in some cases in the more adult stages the columns are only poorly developed (compare Plate III, figs. 1 and 2; in figure 1 the columns reach their maximum development as regards size and number).

The nomenclature of this species has been in a state of considerable confusion. The form was at first called *N. perforatus* by D'Archiac and Haime as well as by de la Harpe, and later by other writers *N. crassus* and *N. aturicus*. Of recent years the name *N. perforatus* has been employed for the megalospheric and *N. obtusus* for the microspheric form.

I have examined specimens of this species from the following localities:—From the upper part of the Middle Kirthar: (*a*) west of Laki village, Sind; (*b*) in the range S. E. of Damach, Thana Bula Khan *taluqa*, Karachi district, Sind (from the first 100 feet of beds below the contact with the Nari series). From the lower part of the Middle Kirthar; (*c*) Kalu Kushtak Nala, due north of Lakhe-ka-kot, Bugti Hills, Baluchistan. (1600 feet below the contact with the Nari series); (*d*) Mardan Nala, Mula River, Kalat State, Baluchistan; (*e*) west and northeast of Pabuni Chauki, on the flank of the Pab Range, Las Bela State, Baluchistan; (*f*) 1½ miles north of Waghapadar (Waggerpudder), Cutch. From the base of the Lower Kirthar; (*g*) Sham plain, Bugti Hills, Baluchistan.

NUMMULITES PERFORATUS, (de Montfort).

1808. ***Egeon perforatus*, (de Montfort). (45).**
1853. ***Nummulites lucasana*, Defr., D'Archiac and Haime (2h).**
1911. ***Nummulites perforatus*, de Mont., Boussac. Form A. (7f).**
1915. ***Nummulites perforatus*, de Mont., Dainelli.**

Plate II, fig. 9.

This species is the megalospheric form of *N. obtusus*. It is rare in India, the only specimens of this species that I have been able

to examine being four from the shales of the Middle Kirthar (B), N. E. of Pabuni Chauki, Las Bela State, Baluchistan, where they occur associated with *N. obtusus*, which is abundant. The diameter of these specimens varies from 5·6 to 3·2 mm., and the thickness from 3·7 to 1·9 mm. In a radius of 1½ mm. there are 5 whorls. The structure of the septal filaments is well shown in the figured specimen, and is typical of the species as found in Europe.

(III) Nummulites with meandriform septal filaments with columns.

NUMMULITES CARTERI, D'Archiac and Haime.

1853. *Nummulina* sp. Carter. (9b).
1853. *Nummulites carteri*, A. and H (21).
1861. *Nummulites carteri*, A. and H., Carter (10d).
1906. *Nummulites carteri*, A. and H., Douvillé. R (25a).

Plate III, figs. 4-5. Plate IV, fig. 1.

This large nummulite has been well described by Carter, and D'Archiac and Haime in naming the species referred to Carter's original figures. The average diameter of the few specimens I have examined is 35 mm. and the thickness 3 to 4 mm. The structure of the septal filaments (see Plate III, fig. 4) shows that the species is related to *N. gizehensis*, but in the former the columns are distinguished by being more elongate and larger, and on the surface by forming granules. The whorls of the median chamber layer of specimens from Sind (Plate III, fig. 5) are more regular than shown in forms ascribed by R. Douvillé to this species from Madagascar. The only locality from which I have specimens of this species is from the upper part of the Middle Kirthar of Sukkur, Sind. I have not found the megalospheric form.

NUMMULITES GIZEHENSIS, (Forks).

1775. *Nautilus ? gizensis*, (Forksal.) (29).
1853. *Nummulites gizehensis*, Ehrenb., D'Archiac and Haime (21).
1853. *Nummulites lyelli*, A. and H. (2j).
1853. *Nummulites caillaudi*, A. and H. (2k).
1911. *Nummulites gizehensis*, (Forks.), Boussac. Form B. cum syn. (7g).
1915. *Nummulites gizehensis*, (Forks.), Dainelli (15d).

Plate III, figs. 3, 6 and 7.

The Indian forms of this species that I have examined have an average diameter of 19 mm., the maximum diameter observed being 28 mm. The average thickness varies from 3·5 to 4 mm., the maximum thickness observed being 4·5 mm. The synonymy of this very variable species has been given by Boussac. As regards the structure of the septal filaments Dainelli and Boussac have illustrated clearly that of specimens from Europe, and the filaments of forms from India resemble these closely. In an equatorial section (Pl. III, fig. 7) there are 15 to 17 whorls in a radius of 10 mm. The septa are slender and curved, the whorl laminæ thick, and the width of the whorls practically the same throughout, after a very rapid growth in the first few whorls. I have not found the megalospheric form of this species. The only locality from which I have specimens of *N. gizehensis* is the upper part of the Middle Kirthar of Sukkur, Sind, where the species is fairly common.

NUMMULITES MACULATUS, sp. nov.

Plate IV, figs. 2-6.

This species of microspheric nummulite resembles *Nummulites gizehensis*. It has a similar thin lenticular shape and numerous narrow whorls. Also the septal filaments are meandriform with columns which in this species are larger and more circular than in *N. gizehensis* (compare Plate, fig. 6). I have not obtained specimens of the megalospheric form.

Diameter of test from 32·8 to 16·0 mm., thickness from 5·7 to 2·9 mm., average ratio of diameter to thickness 5·8 to 1. The shell, which externally is nearly smooth, is rarely flat, being often curved near the edge, so that it is nearly impossible to obtain a complete thin equatorial section of the chamber layer. Border sharp, thickness varying little from the centre to near the periphery. Septal filaments very meandriform (fig. 3), about 60μ in thickness, spaced fairly regularly at a distance of 100 to 250μ. Columns are situated on the filaments and occasionally between them. At right angles to the septal filaments fine transverse hair-like growths are sometimes found, which are only visible under high magnification as in figure 5.

In equatorial section (fig. 2) there are 26 whorls in a radius of 1·2 mm. The width of the whorls varies little from the centre towards the periphery, the septa being numerous and spaced about ·2 to ·3 mm. apart. Septa straight to slightly curved. Chambers rhomboidal in shape, their outer border arched and the width usually greater than the length. Whorl laminæ thick, in parts thicker than the width of the chambers. In an axial section (fig. 6) it may be observed that the exterior portion of each whorl lamina has a wide area of finely perforate shell substance, very different from that of *N. gizehensis*, as shown by D'Archiac and Haime (2m.).

I have only found this species in Cutch State, the localities where it occurs being:—Horizon, Middle Kirthar, (B). (*a*) Upper part of Nummulitic Limestone, about 1 mile northeast of Ber Nana, Cutch (common). (*b*) From 2 miles north of Lakhmirani, Cutch.

Genus, ASSILINA. D'Orbigny.

ASSILINA CANCELLATA, sp. nov.

Plate V, figs. 1-3.

Test flat, lenticular, with a sharp border and thickness nearly uniform from the centre to near the periphery. Average diameter 35 mm., the maximum observed diameter 50 mm. Thickness varies from 3 to 4 mm. The exterior surface in well preserved specimens is smooth and devoid of structure. In certain cases the outer smooth shell lamina has been removed by weathering or, if not, it can be removed artificially with dilute hydrochloric acid so as to lay bare the structure of the septal filaments (as in fig. 1). Their structure is however made most clear by cutting a thin lateral section (see fig. 4), the lamina ot shell substance on either flank of the median chamber layer being about 1 mm. in thickness. The septal filaments consist of radiate ridges corresponding with the septa of the median chamber layer and ridges running along the upper surface of the whorl laminæ. The septal filaments resemble the ridges found on the exterior surface of *Assilina exponens*, from which species *A. cancellata* is readily distinguished by always having a smooth exterior, by being much larger and flatter and by possessing many more whorls.

In an equatorial section of the median chamber layer (fig. 2) it is observed that the form is microspheric. In a radius of 10 mm.

there are 18 whorls, in a radius of 19 mm. 27 whorls ; these increase gradually in width from the centre to the outer margin. The septa are slender and nearly straight, set at right angles to the whorl laminæ. The width of the chambers is greater than their length, the ratio of width to length increasing from the centre to the exterior of the shell.

Occurrence: Horizon, Middle Kirthar (A). (*a*) From Rohri, Sind (common). (*b*) From Kot Deji, Sind. (*c*) From Jhand Mahomed, Sukkur, Sind. (*d*) Specimens in the British Museum (Natural History) labelled " *N. complanatus*, Lam, Alore Hills, Upper Sind, No. P. 22439."

ASSILINA SUBCANCELLATA, sp. nov.

Plate V, fig. 4.

This species is the megalospheric form of *A. cancellata*, and occurs associated with it at Rohri, Sind, where it is common. The diameter of the test, which externally is smooth, varies from 7 to 9 mm., and the average thickness is 2·5 mm. The structure of the septal filaments is the same as in *A. cancellata*. In an equatorial section (fig. 3) there are 5 to 6 whorls in a radius of 3·5 mm., and the diameter of the megalosphere attains 1 mm.

ASSILINA EXPONENS, (Sow).

1837. (1840) *Nummularia exponens*, (Sow.) pars. (59 a) Form B.
1853. *Assilina* sp., Carter (9c).
1853. *Nummulites exponens*, (Sow.), D'Archiac and Haime (2n).
1861. *Assilina exponens*, (Sow.), Carter, (10e) and varieties *a* and *b*.
1863. *Assilina exponens*, (Sow.), Schafhautl. (53b).
1908. *Assilina exponens*, (Sow.), Heim (34a).
1915. *Assilina exponens*, (Sow.), Dainelli (15e).

Plate V, figs. 5-6. Plate VI, fig. 1.

In my recent paper on the *Foraminifera* of the Laki series (48a) I have given account of the dimensions, internal structure and other principal characteristics of *A. exponens*, and have shown how in India this species can be distinguished from *A. granulosa*, D'Archiac. The stratigraphical range of *A. granulosa* is restricted to the Laki series, and *A. exponens* ranges from the upper part of the Ghazij Shales (of the Laki series) to the top of the lower part of the Middle Kirthar.

The figured specimens (Pl. V, fig. 5, Plate VI, fig. 1) are from Cutch, from which State Sowerby described the type of the species. The exterior ornamentation is somewhat variable, the specimens from Cutch having the septa and whorl walls protruding on the surface. Others from Baluchistan (as in Plate V, fig. 6) have small granules along the lines where the septa and whorl walls come to the surface. Nearly smooth, small, globose forms, with an average diameter of about 10 mm. and thickness of 3 to 3·5 mm., are found in localities b and f. In an equatorial section of the shell (Plate VI, fig. 1) the regular growth of the spire and the straightness of the septa are characteristic of the species.

Occurrence.—Horizon, Middle Kirthar (B) : (*a*) 1 mile south of Waghapadar (Waggerpudder), and 3 miles southeast of Sehe, Western Cutch ; (*b*) Mardan Nala, Mula River, Kalat State, Baluchistan ; (*c*) northeast and west of Pabuni Chauki, Las Bela State, Baluchistan (abundant) ; (*d*) Pab Range, west of Shah Bilawal (Bilal) Las Bela State, Baluchistan ; (*e*) Taghoa, Loralai district, Baluchistan. From the upper part of the Ghazij Shales, 600 feet above the Dunghan Limestone ; (*f*) Sham plain, Bugti Hills, Baluchistan.

ASSILINA MAMILLATA, (D'Arch).

1837. (1840) *Nummularia exponens*, Sow. pars. (59*b*). Form A.
1847. *Nummulina mamillata*, D'Arch. (1).
1853. *Nummulites mamillata*, (D'Arch.), D'Archiac, and Haime (2o).
1861. *Assilina obesa*, Carter (10f).
1908. *Assilina mamillata*, (D'Arch.), Heim (34b).
1915. *Assilina mamillata*, (D'Arch.), Dainelli (15f).

Plate VI, fig. 4.

The specific name *A. mamillata* is universally applied to the megalospheric form of *A. exponens* with which it is always found associated. I have described the more important characteristics of the Indian representatives of the species in my recent paper on the Foraminifera of the Laki series (48*a*). *A. obesa*, Carter, is synonymous with this species.

ASSILINA SPIRA, De Roissy.

1805. *Assilina spira*, de Roissy (52).
1853. *Assilina irregularis*, Carter (9*d*).
1853. *Assilina spira*, de Roissy, D'Archiac and Haime (2p).
1911. *Assilina spira*, de Roissy, Boussac, pars. Form B. (7h) cum syn.
1915. *Assilina spira*, de Roissy, Dainelli (15g).

Plate VI, figs. 8-9.

Carter described this species as *A. irregularis* from Sind, and Messrs. D'Archiac and Haime have recorded it from Sind, Subathu (Punjab), and Sylhet (Assam), but it is uncertain if any of the latters' figures refer to specimens from India. This well defined and easily recognized species is abundant in the upper part of the Middle Kirthar of the hills south of Rohri, Sind. The average diameter of the shell is 20 to 25 mm., the maximum diameter observed being 30 mm. The average thickness is 3 mm. Externally the whorl walls and septa usually protrude, but smooth forms with no ornamentation are also found. Internally there are ten whorls in a radius of 11 mm. I have not observed the megalospheric form of this species.

ASSILINA PAPILLATA, sp. nov.

Plate VI, figs. 5-7.

Test nearly flat, lenticular, with rounded border. Average diameter 17 mm., maximum diameter observed 19 mm. Average thickness 2 mm., maximum thickness observed 2·4 mm., the thickness being practically the same at the centre as at the periphery. Average ratio of diameter to thickness 8 to 1.

External ornamentation characteristic and quite distinct from that of related species. In young specimens and in the centre of adults there are large and smooth granules where the septa come to the surface. In the outer portion whorl laminæ are either slightly sunk or protruding, each septa forming a well marked ridge on the surface. Between the septal ridges are small granules arranged irregularly. Internally the primordial chamber is microspheric. In a radius of 7 mm. there are from 9 to 10 whorls. Septa slender, slightly curved near the exterior border. The width of the whorls increases gradually and somewhat irregularly.

In one quadrant of the	3rd	whorl there are	4—6	septa.
,,	4th	,,	6—7	,,
,,	5th	,,	6—7	,,
,,	6th	,,	7—8	,,
,,	7th	,,	8—9	,,
,,	8th	,,	9—10	,,
,,	9th	,,	10—11	,,
,,	10th	,,	11	,,

Occurrence.—Horizon, Middle Kirthar (A.): (*a*) Sukkur, Sind; (*b*) Kubba Shadi Shahid, 4 miles southeast of Khairpur, Sind (fairly common); (*c*) Kort Deji, Sind; (*d*) Range southeast of Damach, Thana Bula Khan *taluqa*, Karachi district, Sind (common); (*e*) west of Laki village, Sind.

ASSILINA SUBPAPILLATA, sp. nov.

Plate VI, figs. 2-3.

This species is the megalospheric form of *A. papillata* described above. and is always found associated with it. The diameter of the shell varies from 5 to 6 mm. and the average thickness is 2 mm. Exteriorly the granules near the centre are very strong, the central part of the shell being usually depressed. In the outer whorl the septa form ridges on the surface with granules between as in *A. papillata*. In an equatorial section it is seen that the diameter of the megalosphere is about ·3 mm. In a radius of 3 mm. there are 6 whorls, which increase gradually in width from the centre to the periphery. The septa are slightly curved, in one quadrant of the second whorl there being 4 septa, in one quadrant of the 3rd whorl 5-6 septa.

Genus, ORBITOIDES. D Orbigny.

Subgenus, DISCOCYCLINA, Gümbel.

DISCOCYCLINA DISPANSA, (Sowerby).

1837. (1840). *Lycophyris dispansus*, Sowerby (58c).
1853. non *Lycophyris dispansus*, Sowerby, Carter (9e).
1861. ? *Orbitoides dispansa*, (Sow.), Carter (10g).
1868 to 1888. non *Orbitoides dispansa*, (Sow.), Gümbel, Hantken, Brady, Fritsch, Martin, Jennings. For references see Sherborn (54).
1896. non *Orbitoides dispansa*, (Sow.), Verbeek and Fennema cum syn. (62a).
1897. *Orbitoides dispansa*, (Sow.), Medlicot and Blanford (44).
1900. non *Orbitoides dispansa*, (Sow.), Martin (42).
1900. non *Orbitoides* (*Discocyclina*) *dispansa* (Sow.), Jones and Chapman (36)
1903. non *Orthophragmina dispansa*, (Sow.), Schlumberger (56).
1912. non *Orthophragmina dispansa*, (Sow.), Douvillé (19c).
1915. non *Orthophragmina dispansa*, (Sow.), Martin (43.)
1917. non *Orthophragmina dispansa*, (Sow.), Checchia-Rispoli (12) cum syn.

Plate VII, figs. 1, 2, 3 and 5.

Sowerby originally described this species from Baboa Hill and Waghapadar (Waggerpudder) in Cutch as follows :— " Lenticular, thick, with very thin, expanded, sharp-edged margin ; grains on the surface largest in the centre of the disk. Diameter ½ an inch ". Two important characteristics of the species are made clear by Sowerby's description and figures. One is that the columns of shell matter, where they protrude on the surface, form granules which are of larger diameter at the centre than near the periphery of the shell. The second is shown in his figure (Plate XXIV, fig. 1, *a*) illustrating that in an axial section the columns are seen to increase considerably in diameter from the centre to the periphery. These features above are sufficient to distinguish this species from D. *javana* var. *indica*, described below.

Owing to Sowerby's description not being sufficiently detailed much confusion has arisen around the nomenclature of the species, and many forms have been incorrectly referred to it. The above list includes the more important references to *D. dispansa* from India and the islands of the East Indies. All the forms referred to *D. dispansa* in Europe appear to have been incorrectly placed in this species.

I have been unable to find the type specimens of *D. dispansa* in the British Museum (Natural History), but have collected specimens myself from one of the type localities, namely Waghapadar in Cutch, where *D. dispansa* occurs in the same beds as *D. javana*, var. *indica*, and *D. sowerbyi*, which are described below. The following is a more complete description of the morphology of the shell of *D. dispansa*.

Description.—Test rounded, globular to fairly flat, lenticular, with a wide raised mamelon. Border sharp. Average diameter 8 mm., maximum diameter 10·5 mm. Average thickness 3·5 mm. Exterior granules, the terminations of the vertical columns of shell matter large, irregular in shape and greatest in size at the centre of the shell. A thin lateral section a short distance below the upper surface exhibits well the structure of the columns (fig. 3). It may be seen that some of the columns are circular and others elongate-ovoid to C-shaped, their width (at right angles to the radius) is from ·15 to ·25 mm., their length (parallel to the radius) varies from ·2 to ·4 mm. Surrounding each column there is a rosette of usually 9 to 12 septa.

In an axial section (fig. 5) it may be seen that the median chamber layer is only about ·075 mm. in thickness. The columns of shell substance, where they start from the flanks of the median chamber layer, are narrow, and towards the periphery increase considerably in diameter. Occasionally near the outer margin they appear to bifurcate, this being due to their irregular shape, as is seen in horizontal section. An equatorial section of the median chamber layer is known to be of little value in the specific determination of the species of the genus *Discocyclina.* The forms of this species that I have examined were microspheric, the arrangement of the annular whorls of cells being indistinguishable from that found in *D. javana,* var. *indica* described below. There are about 60 whorls in a radius of 3 mm.

Previous Reference to the Species in India.—In 1853 Carter referred to *D. dispansa* a foraminifer, which has been classified in another genus *Spiroclypeus* (see Douvillé 44). In 1861 Carter gave an excellent description of the internal structure of a species of the genus *Discocyclina,* but omitted certain important details from his figures, an omission which renders it uncertain if he were describing *D. dispansa.* For example, in his diagram (Plate XVI, fig. 1*a*) showing a lateral section of the columnar structure, the columns are much more regular than is typical of the species (compare fig. 3). Also in his diagram (fig. 1 b) the columns in vertical section are much narrower than is found in *D. dispansa* (compare fig. 5). Except for the figures of the species of Blanford and Medlicot all the specimens referred to in the list above are more closely related to *D. javana* than to *D. dispansa.*

Occurrence.—Horizon, Middle Kirthar (B) of the following localities: (*a*) 1 mile south of Waghapadar (Waggerpudder) Cutch (common); (*b*) 2 miles Southwest of Godhathad (Gothahad), Cutch; (*c*) 2 miles west of Lakhmirani, Cutch. From the Middle Kirthar (B), about 2,500 feet above the contact of the Lower Kirthar with the Ghazij Shales, abundant in a thin limestone band: (*d*) Northeast of Drug, Loralai district, Baluchistan; (*e*) Taghoa, Loralai district, Baluchistan

DISCOCYCLINA JAVANA, (Verbeek), var. INDICA, nov.

1870. ***Orbitoides dispansa,*** **Sowerby, Gümbel. pars. (31a).**
1892. Var. of ***Orbitoides papyracea,*** **Boubée var.** ***javana,*** **Verbeek (61).**
1896. ***Orbitoides papyracea,*** **Boubée var.** ***javana,*** **Verbeek, Verbeek and Fennema, (62b).**
1912. Var. of ***Orthophragmina javana,*** **(Verbeek), Douvillé (19d).**

Plate VII, figs. 4, 6, and 7. Plate VIII, fig. 4.

The Indian variety differs from *D. javana* by being smaller and proportionately more globose. The average diameter of the Javan forms is from 20 to 30 mm., and that of the Indian forms 11 mm., the maximum diameter observed being 13·1 mm. The Indian variety is globose, lenticular, with a sharp border. The thickness of the Javan types is from 6 to 3 mm., and that of the Indian forms from 4·7 to 3·4 mm., the average thickness being 4 mm. The Indian variety of this species from Sind has been incorrectly described as *D. dispansa* by Gümbel. In his figures 40 and 41 he illustrates young forms, and in figures 44 and 45 shows the cells of the median chamber layer. His figures 46 and 47 show the structure of the columns in the lateral chamber layer, and these are clearly different from those of *D. dispansa* described above.

A lateral section (Plate VIII, fig. 4) of the columnar chamber layer a short distance below the upper surface shows that the diameter of the columns varies from ·1 to ·13 mm. The columns are sub-circular in cross section and the distance from the centre of one column to another is from ·18 to ·23 mm., each column being surrounded by 5 to 6 septa.

In axial section (Plate VII, fig. 7) the columns of shell substance vary little in diameter from the centre to the upper and lower lateral surfaces. Median chamber layer narrow, as in *D. dispansa*. In equatorial section of the median chamber layer (Plate VII, fig. 4) the specimens examined were microspheric. Annular whorls of cells numerous, near the centre 40 in a radius of 2 mm. Cells two or three times as long as wide, there being about 25 cells in 1 mm. of circumference at about 2 mm. from the centre of the shell. Average length of the cells ·06 mm. and width ·03 mm.

Occurrence.—I have examined specimens of this species which is common in the Middle Kirthar (B): (*a*) 1 mile south of Waghapadar (Waggerpudder), 3 miles southwest of Sehe, 2 miles west of Lakhimirani, 1½ miles east of Jhadwan, Western Cutch. From about 2,600 feet above the contact of the Lower Kirthar with the Ghazij Shales; (*b*) east of Garmaf hot spring, Buzdar tribal tract, Dera Ghazi Khan district, S. W. Punjab; (*c*) from Taghoa, Loralai district, Baluchistan; (*d*) from Kalu Kushtak Nala, 5 miles northwest of Dera Bugti, Bugti Hills, Baluchistan. From the shales of the Middle Kirthar; (*e*) northeast and west of Pabuni Chauki, Pab Range, Las Bela State, Baluchistan; (*f*) Madras Nala, Mula River, Kalat State, Baluchistan.

DISCOCYCLINA SOWERBYI, nom. nov.

1820. non *Lenticulites ephippium,* Schlotheim (55).
1837. (1840) *Lycophris ephippium,* Sowerby (58d).
1853. *Lycophris ephippium,* Sowerby, Carter (9f).
1870. non *Orbitoides ephippium,* Schloth. Gumbel (31b).
1876. ? *Orbitoides ephippium,* (Sow.), Zittel (68).
1922. non *Discocyclina ephippium,* (Schloth.), Douvillé (24a).

Plate VIII, figs. 1, 2 and 3.

Sowerby's original description of this species is as follows:— "Orbicular, depressed, curved so as to resemble a saddle, with gently elevate umbo on each side; margin thick, obtuse, with a narrow waved keel in the middle; grains on the surface small and equal. Diameter $1\frac{1}{2}$ inches, thickness 3 lines." Writing of *Lycophris ephippium* and *L. dispansa* he also states that "these two fossils may possibly be different stages of growth of the same species."

Regarding the shape of the test in adult forms it is saddle-shaped as in the type specimen of Sowerby's figure 15, preserved in the British Museum (Natural History). The young forms are however very variable in shape, some being flat to wavy, subcircular discs, with a thickness of about 4 mm. The largest saddle-shaped form that I have examined is 33 mm. in diameter and 7 mm. in thickness. The thickness is nearly uniform at all points of the test except at a slightly inflated area by the central umbo.

The structure of the columns of shell substance is quite distinct from that of *D. dispansa,* described above, but is similar to that of *D. javana* var. *indica.* The columns are subcircular in cross-section from ·1 to ·15 mm. in diameter, the distance from centre to centre of neighbouring columns being ·2 to ·3 mm. Surrounding each column is a rosette of 5 to 7 septa (see figs. 2 and 3). The columns differ from those of *D. ephippium,* Schloth., which, according to Douvillé, attain ·1 mm. in diameter and are surrounded by 11 to 13 petals.

In axial section (fig. 1) it is seen that the median chamber layer is narrow and increases in height from the centre to the periphery, where it has a maximum height of ·1 mm. Walls of the annular chambers arched exteriorly. Columns of shell substance in the lateral laminæ nearly uniform in thickness from the centre to the outer surface of the shell. Owing to the irregular shape of the test it is not possible to obtain a complete equatorial section of the median

chamber layer. All the specimens of which sections were obtained were microspheric: the chambers were longer than wide, the width varying from ·05 to ·1 mm. and the average length being ·1 mm.

Occurrence.—I have examined specimens of *D. sowerbyi* from the Middle Kirthar (B) of the following localities *a* to *e*.—(*a*) 1½ miles north of Waghapadar (Waggerpudder), 2 miles southwest of Godhathad (Gothahad), 1½ miles east of Jahdwan, and 2 miles west of Lakhimirani, Western Cutch; (*b*) Taghoa, Loralai district, Baluchistan. From about 2,600 feet above the contact of the Lower Kirthar with the Ghazij Shales; (*c*) east of Drug, Loralai district, Baluchistan. From the same stratigraphical horizon as c; (*d*) East of Garmaf, Buzdar tribal tract, Dera Ghazi Khan district, S. W. Punjab. From the shales of the Middle Kirthar; (*e*) Mardan Nala, Mula River, Kalat State; Baluchistan. From the Middle Kirthar (A); (*f*) Kot Deji, Sind; (*g*) West of Laki village, Sind.

DISCOCYCLINA UNDULATA, sp. nov.

Plate VII, figs. 8, 9. Plate VIII, fig. 5.

Shell flat. lenticular, with a sharp border and a prominent central mamelon. Surface uniformly granular, granules on the marginal flat portion of the shell sometimes arranged concentrically, their size not varying from the centre to the periphery. Diameter of test varies from 8 to 11 mm., thickness from 2·0 to 2·5 mm.

In a laterial section a short distance below the upper surface (fig. 9) the diameter of the columns of shell substance varies from 70 to 100μ, the average being 87μ. The distance from centre to centre of neighbouring columns is 270 to 160μ, the average distance being 210μ. Each column is surrounded by 6 to 7 septa, which are gently and irregularly curved in their course from column to column. *D. undulata* belongs to the group of *D. archiaci*, Schlumberger (see Douvillé, 21*b*) and is readily distinguished from any of the related forms by the above characteristic wavy arrangement of the septa surrounding the columns.

In axial section (*fig.* 5) the height of the median chamber layer is from 40 to 50μ, and the megalospheric primordial chamber elongate-oval in cross-section, the average length 600μ, and height 250μ. In equatorial sections all the specimens examined were megalospheric, the primordial chamber being subcircular to oval with a diameter of 770 to 440μ. Beginning from the border of the pri-

mordial chamber in a radius of 1 mm. there are about 14 whorls of cells, each about ·04 mm. in width.

Occurrence:—This species is abundant in the Middle Kirthar (B), east of Garmaf, Buzdar tribal tract, Dera Ghazi Khan district, S. W. Punjab, being found in beds about 2,600 feet above the contact of the Lower Kirthar with the Ghazij Shales. At this locality there are some thin limestones entirely made up of this fossil, which I have not found elsewhere.

Subgenus, ACTINOCYCLINA, Gümbel.

ACTINOCYCLINA ALTICOSTATA, sp. nov.

Plate VIII, figs. 6, 7 and 8.

Shell circular with a central mamelon, surrounded by 8 to 12 fairly wide prominent rays. Diameter of the test varies from 8 to 15 mm. There are 8 or 9 rays starting from the centre, and at a distance of about 3 mm. from the centre other rays appear, which are only seen fully developed in adult individuals. The surface is covered with fine granules.

In an equatorial section (fig. 6) of a megalospheric individual the arrangement of the first chambers is as in that of *Orthophragmina radians*, D'Archiac as figured by Schlumberger (57*a*). The maximum diameter of the first chamber is 260μ, and that of the partially circumambient chamber 400μ. The rectangular chambers become narrower and more elongate from the centre to the periphery of the shell, their length varying from 70 to 90μ, and their width from 20 to 40μ. In the lateral laminæ of shell substance the diameter of the columns is not over 100μ, and each is surrounded by 4 to 6 petals.

This species belongs to the group of *A. radians*, D'Archiac (see Douvillé. H. 24*c*). It is related to *A. lucifera*, Kaufmann (37), which has 10 to 16 narrow rays on the surface and a diameter of 5 to 6 mm. It closely resembles *Orthophragmina* sp. of Schlumberger (57*b*), which specimen is incomplete. The nearest related species that has been described is *Orthophragmina colcanapi*, Douvillé, R. (25*b*), from which *A. alticostata* may be distinguished by its smaller diameter and by having fewer rays which do not bifurcate. This fossil is rare in India, and I have only obtained 12 specimens from the Middle Kirthar (B), 2 miles west of Lakhimirani and 1¼ miles east of Shadwan, Western Cutch.

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(65) VREDENBURG, E. The Geology of Sarawan, Jhalawan, Mekran and the State of Las Bela. *Rec. Geol. Surv. Ind.*, Vol. XXXVIII (1909), pp. 189-215.

(66) VREDENBURG, E. Introductory Note on the Stratigraphy of the Ranikot Series in "The Mollusca of the Ranikot Series" by Cossman and Pissaro. *Pal. Ind.* New Ser., Vol. III, Mem. No. 1 (1909); table opposite page VI.

(67) WYNNE, A. B. . The Geology of Cutch. *Mem. Geol. Surv. Ind.*, Vol. IX (1869), pp. 1-289.

(68) ZITTEL, K. A. . . Handbuch von Palæontologie. Vol. I (1876), p. 103 ; fig. 43.

EXPLANATION OF PLATES.

PLATE I.

FIGS. 1 and 2.—(×3). *Nummulites stamineus*, sp. nov. Kalu Kushtak Nala, 5 miles N. W. of Dera Bugti, Bugti Hills, Baluchistan. Holotype, fig. 2 :—2 miles S. W. of Godhathad (Gothahad), Cutch.

FIG. 3—(×5). *N. stamineus*, sp. nov. Equatorial section ; 1 mile S. of Waghapadar (Waggerpudder), Cutch.

FIGS. 4, and 5.—(×5). *N. beaumonti*, D'Arch. W. of Dawagar, Dera Ghazi Khan foothills, S. W. Punjab. Fig. 5 :—Equatorial section.

FIGS. 6, and 7.—(×5) *N. laevigatus*, (Brug.) ; Rohri, Sind. Fig. 6 :—Equatorial section. Fig. 7 :—Lateral section.

PLATE II.

FIGS. 1, 2 and 3 —(×3). *Nummulites acutus*, Sow. Figs. 1, and 2 :—2 miles S. W. of Godhathad (Gothahad), Cutch. Fig. 3 :—Sowerby's original type from Lakhpat (Lukput), Cutch.

FIG. 4.—(×5). *N. acutus*, Sow. Lateral section ; same locality as fig. 1.

FIGS. 5, 6, 7 and 8.—(×5). *N. scaber*, Lam. Fig. 5 :—Axial section ; Rohri, Sind. Fig. 6 :—Lateral section ; W. of Laki village, Sind. Fig. 7 :—Lateral section ; Rohri, Sind. Fig. 8 :—Equatorial section ; Rohri, Sind.

FIG. 9.—(×5). *N. perforatus*, (de Mont.); N. E. of Pabuni Chauki, Las Bela State, Baluchistan.

FIG. 10—(×2). *N. obtusus*, Sow. Mardan Nala, Mula River, Kalat State, Baluchistan.

PLATE III.

FIGS. 1 and 2.—(×5). *Nummulites obtusus*, Sow. Lateral sections. Fig. 1 :—Sham plain, Bugti Hills, Baluchistan. Fig. 2 :—Kalu Kushtak Nala, 5 miles N. W. of Dera Bugti, Bugti Hills, Baluchistan.

FIG. 3.—(×2). *N. gizehensis*, (Forks.) ; Rohri, Sind.

FIGS. 4 and 5.—(×5). *N. carteri*, D'Arch. and Haime. Sukkur, Sind. Fig. 4 :—Lateral section. Fig. 5 :—Equatorial section.

FIGS. 6 and 7.—(×5). *N. gizehensis*, (Forks.) Rohri, Sind. Fig. 6 —Lateral section Fig. 7 ;—Equatorial surface.

PLATE IV.

FIG. 1.—(×2). *N. carteri*, D'Arch. and Haime. Sukkur, Sind.
FIG. 2.—(×5). *N. maculatus*, sp. nov. Equatorial surface; 1 mile N. E. of Ber Nani, Cutch.
FIG. 3.—(×2). *N. maculatus*, sp: nov. Holotype. Same locality as fig. 2.
FIG. 4.—(×5). Do. Lateral section. Same locality.
FIG. 5.—(×10). Do. Axial section. Same locality.
FIG. 6.—(×25). Do. Part of lateral section of fig. 4 magnified.

PLATE V.

FIG. 1.—(×2). *Assilina cancellata*, sp. nov. Rohri, Sind. Holotype.
FIG. 2.—(×5). Do. Equatorial section; same locality.
FIG. 3.—(×5). Do. Lateral section; same locality.
FIG. 4.—(×5). *A. subcancellata*, sp. nov. Equatorial section; same locality.
FIGS. 5 and 6.—(×3). *A. exponens*, (Sow.). Fig:—5·3 miles S. E. of Sehe, Cutch. Fig. 6;—W. of Pabuni Chauki, Las Bela State, Baluchistan.

PLATE VI.

FIG. 1.—(×5). *Assilina exponens*, (Sow.). 1 mile S. of Waghapadar (Waggerpudder), Cutch. Equatorial section.
FIGS. 2 and 3.—(×3). *A. subpapillata*, sp. nov. Fig. 2:— Holotype. Kubba Shadi Shahid, S.E. of Khairpur, Sind. Fig. 3:—S. E. of Damach, Thana Bula Khan *taluqa*, Karachi district, Sind.
FIG. 4.—(×2). *A. mamillata*, (D'Arch.); 3 miles S. E. of Sehe, Cutch.
FIG. 5.—(×3). *A. papillata*, sp. nov. Holotype; same locality as fig. 3.
FIG. 6.—(×5). *A. papillata*, sp. nov. Equatorial Section. Kot Deji, Sind.
FIG. 7.—(×3). *A. papillata*, sp. nov.; same locality as fig. 2.
FIGS. 8 and 9.—(×2). *A. spira*, de Roissy. Rohri, Sind.

PLATE VII.

FIGS. 1 and 2.—(×5). *Discocyclina dispansa*, (Sow.). Fig. 1:—Neotype. 1 mile S. of Waghapadar (Waggerpudder), Cutch.
FIG. 3.—(×7·5). *D. dispansa*, (Sow.). Lateral Section; same locality as fig. 1.
FIG. 4.—(×7·5). *D. javana*, (Verbeek.) var. *indica*, nov. Lateral section; same locality as fig. 1.
FIG. 5.—(×7·5). *D. dispansa*; (Sow.). Axial section; same locality as fig. 2.
FIG. 6.—(×5). *D. javana*, (Verbeek.) var. *indica*, nov.; same locality as fig. 1.
FIG. 7.—(×7·5). Do. Axial section; same locality as fig. 1.
FIG. 8.—(×5). *D. undulata*, sp. nov. Holotype. E. of Garmaf, Dera Ghazi Khan district, S. W. Punjab.
FIG. 9.—(×20). Do. Lateral section; same locality as fig. 8.

PLATE VIII.

FIG. 1.—(×10). ***Discocyclina sowerbyi***, **nom. nov. Axial section; 2 miles S. W. of Godhathad (Gothahad), Cutch.**

FIG. 2.—(×10). Do. View of portion of the exterior.

FIG. 3.—(×10). Do. Lateral section.

FIG. 4.—(×20). *D. javana* (Verbeek.) var. *indica*, nov. Equatorial section. Same locality as Pl. VII, fig. 1.

FIG. 5.—(×7·5). *D. undulata*, sp. nov. Axial section; same locality as Pl. VII, fig. 8.

FIG. 6.—(×11). *Actinocyclina alticostata*, sp. nov. Equatorial section; W. of Lakhimirani, Cutch.

FIGS. 7 and 8.—(×5). *A. alticostata*, sp. nov. Fig. 8:—Holotype. Same locality as fig. 6.

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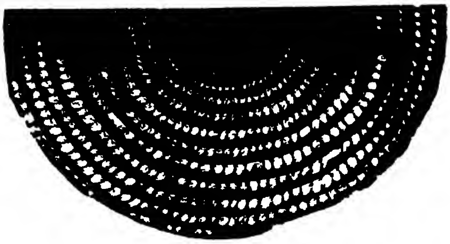

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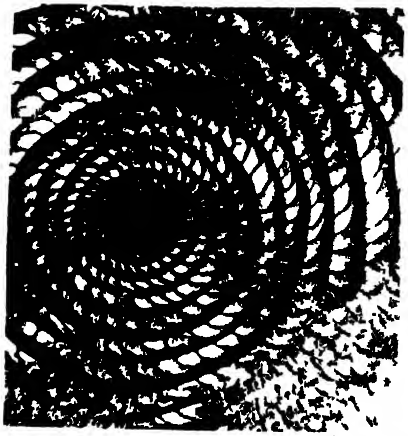

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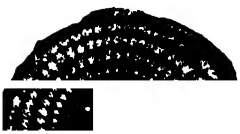

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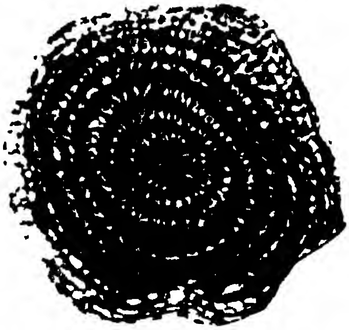

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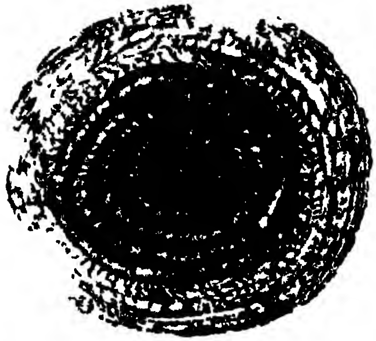

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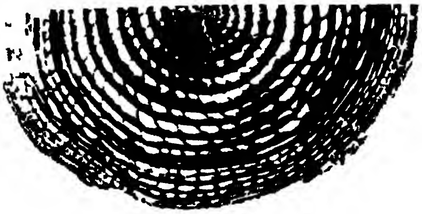

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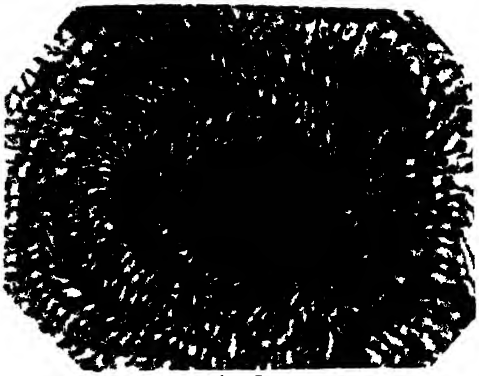

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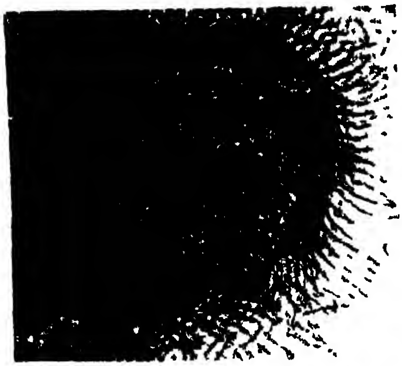

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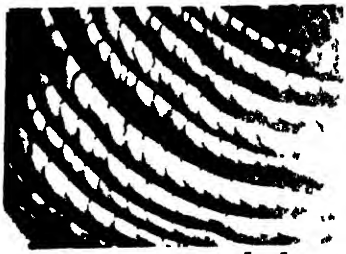

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Photo Mezo W. I F. Nuttal. *G. S. I. Calcutta.*

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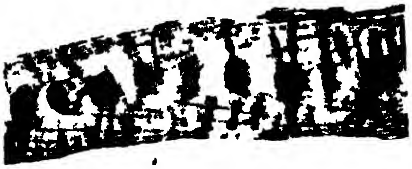

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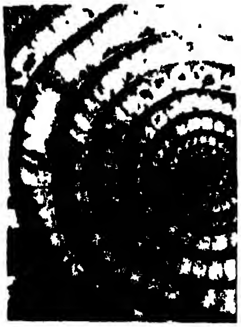
ASSILINA



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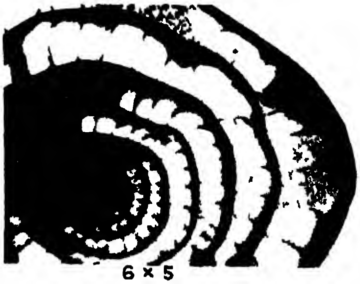

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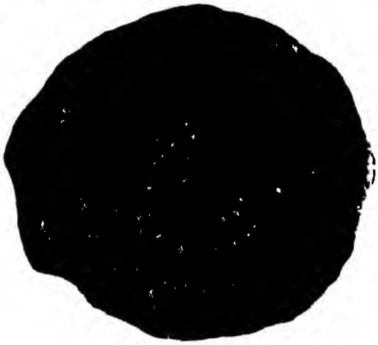

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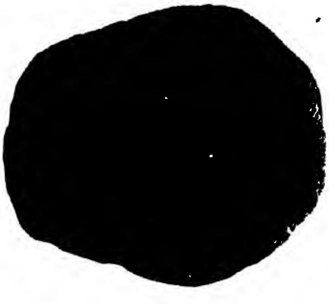

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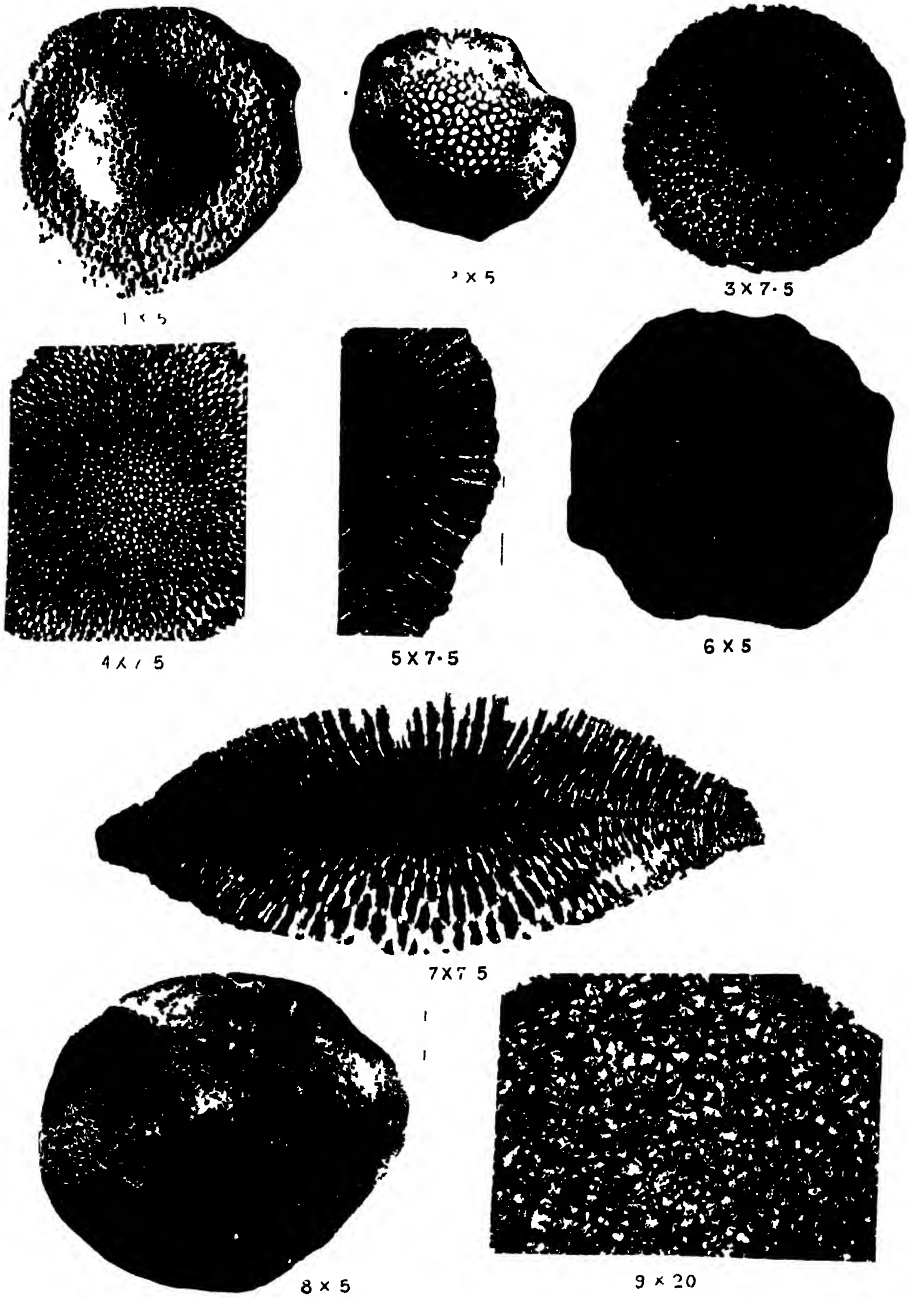

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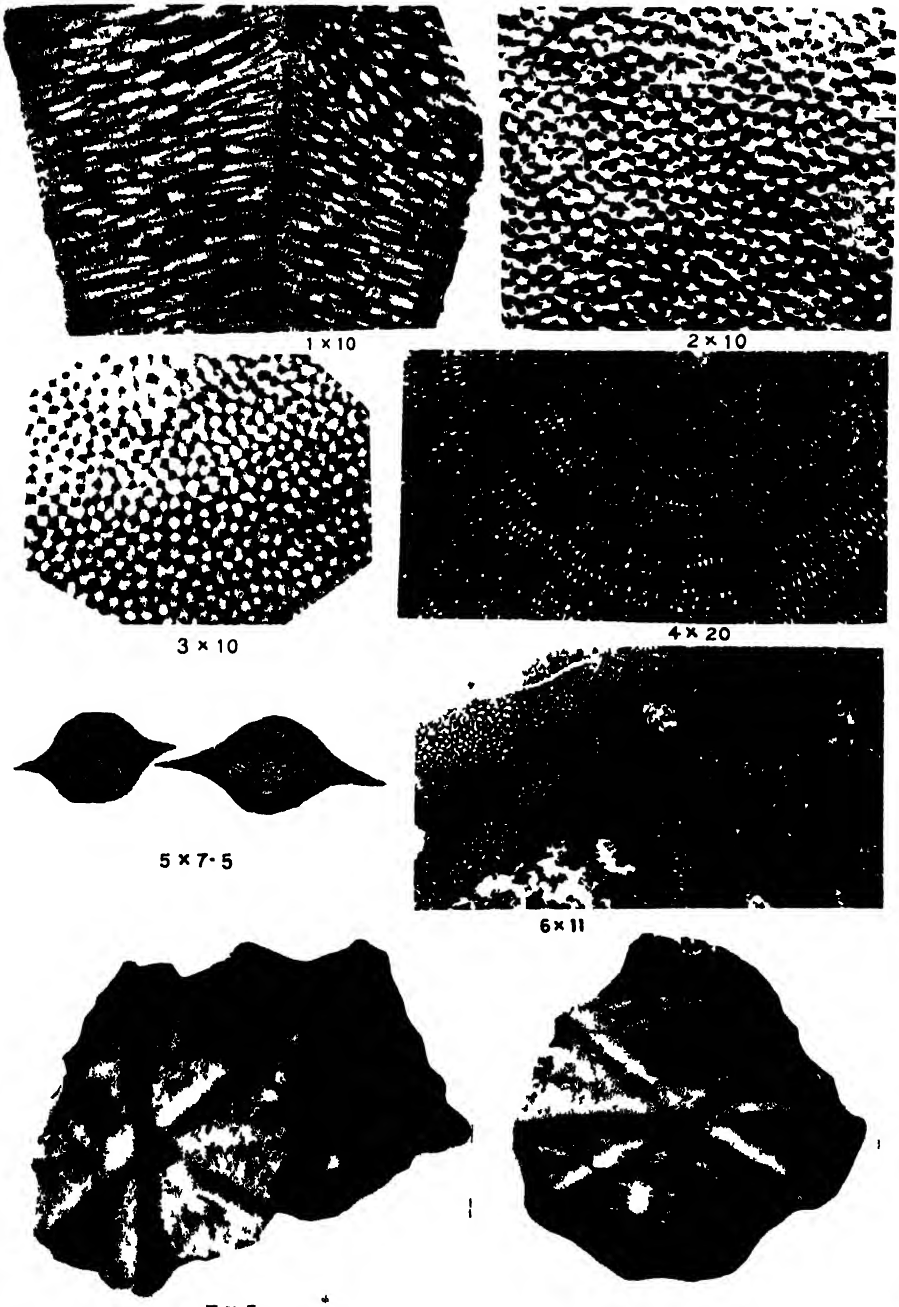
DISCOCYCLINA.



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DISCOCYCLINA AND ACTINOCYCLINA.

Cobaltite and danaite from Khetri mines, Rajputana; with remarks on Jaipurite (Syenite). Zinc-ore (Smithsonite and Blende) with barytes in Karnul district, Madras. Mud eruption in island of Cheduba.

Part 3 (out of print).—Artesian borings in India. Oligoclase granite at Wangtu on Sutlej, North-West Himalayas. Fish-plate from Siwaliks. Palæontological notes from Hazaribagh and Lohardagga districts. Fossil carnivora from Siwalik hills.

Part 4.—Unification of geological nomenclature and cartography. Geology of Arvali region, central and eastern. Native antimony obtained at Pulo Obin, near Singapore. Turgite from Juggiapett, Kistnah District, and zinc carbonate from Karnul, Madras. Section from Dalhousie to Pangi, *viâ* Sach Pass. South Rewah Gondwana basin. Submerged forest on Bombay Island.

VOL. XV, 1882.

Part 1 (out of print).—Annual report for 1881. Geology of North West Kashmir and Khagan. Gondwana labyrinthodonts (Siwalik and Jamna mammals). Geology of Dalhousie, North-West Himalaya. Palm leaves from (tertiary) Murree and Kasauli beds in India. Iridosmine from Noa-Dihing river, Upper Assam, and Platinum from Chutia Nagpur. On (1) copper mine near Yongri hill, Darjiling district; (2) arsenical pyrites in same neighbourhood: (3) kaolin at Darjiling. Analyses of coal and fire-clay from Makum coal-fields, Upper Assam. Experiments on coal of Pind Dadun Khan, Salt range, with reference to production of gas, made April 29th, 1881. International Congress of Bologna.

Part 2 (out of print).—Geology of Travancore State. Warkilli beds and reported associated deposits at Quilon, in Travancore. Siwalik and Narbada fossils. Coal-bearing rocks of Upper Rer and Mand rivers in Western Chutia Nagpur. Pench river coal-field in Chhindwara district, Central Provinces. Boring for coal at Engsein, British Burma. Sapphires in North-Western Himalaya. Eruption of mud volcanoes in Cheduba.

Part 3.—Coal of Mach (Much) in Bolan Pass, and of Sharigh on Harnai route between Sibi and Quetta. Crystals of stilbite from Western Ghats, Bombay. Traps of Darang and Mandi in North-Western Himalayas. Connexion between Hazara and Kashmir series. Umaria coal-field (South Rewah Gondwana basin). Daranggiri coal fields, Garo Hills, Assam. Coal in Myanoung division, Henzada district.

Part 4 (out of print).—Gold-fields of Mysore. Borings for coal at Beddadanol, Godavari district, in 1874. Supposed occurrence of coal on Kistna.

VOL. XVI, 1883.

Part 1.—Annual report for 1882. Richthofenia. Kays (Anomia Lawrenciana, Koninck). Geology of South Travancore. Geology of Chamba. Basalts of Bombay.

Part 2 (out of print).—Synopsis of fossil vertebrata of India. Bijori Labyrinthodont. Skull of Hippotherium antilopinum. Iron ores, and subsidiary materials for manufacture of iron, in north-eastern part of Jabalpur district. Laterite and other manganese-ore occurring at Gosalpore, Jabalpur district. Umaria coal-field.

Part 3.—Microscopic structure of some Dalhousie rocks. Lavas of Aden. Probable occurrence of Siwalik strata in China and Japan. Mastodon angustidens in India. Traverse between Almora and Mussooree. Cretaceous coal-measures at Borsora, in Khasia Hills, near Laour, in Sylhet.

Part 4 (out of print).—Palæontological notes from Daltonganj and Hutar coal-fields in Chota Nagpur. Altered basalts of Dalhousie region in North-Western Himalayas. Microscopic structure of some Sub-Himalayan rocks of tertiary age. Geology of Jaunsar and Lower Himalayas. Traverse through Eastern Khasia, Jaintia, and North Cachar Hills. Native lead from Maulmain and chromite from the Andaman Islands. Fiery eruption from one of the mud volcanoes of Cheduba Island, Arakan. Irrigation from wells in North-Western Provinces and Oudh.

VOL. XVII, 1884.

Part 1.—Annual report for 1883. Smooth-water anchorages or mud-banks of Narrakal and Alleppy on Travancore coast. Billa Surgam and other caves in Kurnool district. Geology of Chauari and Sihunta parganas of Chamba. Lyttonia, Waagen, in Kuling series of Kashmir.

Part 2 (out of print).—Earthquake of 31st December 1881. Microscopic structure of some Himalayan granites and gneissose granites. Choi coal exploration. Re-discovery of fossils in Siwalik beds. Mineral resources of Andaman Islands in neighbourhood of Port Blair. Intertrappean beds in Deccan and Laramie group in Western North America.

Part 3 (out of print).—Microscopic structure of some Arvali rocks. Section along Indus from Peshawar Valley to Salt-range. Sites for boring in Raigarh-Hingir coal-field (first notice). Lignite near Raipore, Central Provinces. Turquoise mines of Nishapur, Khorassan. Fiery eruption from Minbyin mud volcano of Cheduba Island, Arakan. Laungyin coal-field, South-Western Khasia Hills. Umaria coal-field.

Part 4.—Geology of part of Gangasúlan pargana of British Garhwal. Slates and schists imbedded in gneissose granite of North-West Himalayas. Geology of Takhti-Suleiman. Smooth water anchorages of Travancore coast. Auriferous sands of the Subansiri river, Pondicherry lignite, and phosphatic rocks at Musuri. Billa Surgam caves.

Vol. XVIII, 1885

Part 1 (out of print).—Annual report for 1884. Country between Singareni coal-field and Kistna river. Geological sketch of country between Singareni coal-field and Hyderabad. Coal and limestone in Doigrung river near Golaghat, Assam. Homotaxis, as illustrated from Indian formations. Afghan field notes.

Part 2.—Fossiliferous zone in Lower Himalaya, Garhwal. Age of Mandhali series in Lower Himalaya. Siwalik camel (Camelus Antiquus nobis ex Falc. and Caut. MS.) Geology of Chamba. Probability of obtaining water by means of artesian wells in plains of Upper India. Artesian sources in plains of Upper India. Geology of Aka Hills. Alleged tendency of Arakan mud volcanoes to burst into eruption most frequently during rains. Analyses of phosphatic nodules and rock from Mussooree.

Part 3 (out of print). Geology of Andaman Islands. Third species of Merycopotamus. Percolation as affected by current. Pirthalla and Chandpur meteorites. Oil-wells and coal in Thayetmyo District, British Burma. Antimony deposits in Maulmain district. Kashmir earthquake of 30th May 1885. Bengal earthquake of 14th July 1885.

Part 4 (out of print). Geological work in Chhattisgarh division of Central Provinces. Bengal earthquake of 14th July 1885. Kashmir earthquake of 30th May 1885. Excavations in Billa Surgam caves. Nepaulite. Sabetmahet meteorite.

Vol. XIX, 1886.

Part 1. Annual report for 1885. International Geological Congress of Berlin. Palæozoic Fossils in Olive group of Salt-range. Correlation of Indian and Australian coal-bearing beds. Afghan and Persian Field-notes. Section from Simla to Wangtu, and petrological character of Amphibolites and Quartz Diorites of Sutlej valley.

Part 2 (out of print). Geology of parts of Bellary and Anantapur districts. Geology of Upper Dehing basin in Singpho Hills. Microscopic characters of eruptive rocks from Central Himalayas. Mammalia of Karnul Caves. Prospects of finding coal in Western Rajputana. Olive group of Salt-range. Boulder-beds of Salt-range. Gondwana Homotaxis.

Part 3 (out of print).—Geological sketch of Vizagapatam district, Madras. Geology of Northern Jesalmer. Microscopic structure of Malani rocks of Arvali region. Malanjkhandi copper ore in Balaghat district, C. P.

Part 4 (out of print). Petroleum in India. Petroleum exploration at Khátan. Boring in Chhattisgarh coal-fields. Field notes from Afghanistan: No. 3, Turkistan. Fiery eruption from one of the mud volcanoes of Cheduba Island, Arakan. Nammianthal aerolite. Analysis of gold dust from Meza valley, Upper Burma.

Vol. XX, 1887.

Part 1. Annual report for 1886. Field notes from Afghanistan: No. 4, from Turkistan to India. Physical geology of West British Garhwal; with notes on a route traversed through Jaunsar-Bawar and Tiri-Garhwal. Geology of Garo Hills. Indian image-stones. Soundings recently taken off Barren Island and Narcondam. Talchir boulder-beds. Analysis of Phosphatic Nodules from Salt-range, Punjab.

Part 2.—Fossil vertebrata of India. Echinoidea of cretaceous series of Lower Narbada Valley. Field-notes: No. 5 to accompany geological sketch map of Afghanistan and North-Eastern Khorassan. Microscopic structure of Rajmahal and Deccan traps. Dolerite of Chor. Identity of Olive series in east with speckled sandstone in west of Salt-range in Punjab.

Part 3.—Retirement of Mr. Medlicott. J. B. Mushketoff's Geology of Russian Turkistan. Crystalline and metamorphic rocks of Lower Himalaya, Garhwal, and Kumaun, Section I. Geology of Simla and Jutogh. 'Lalitpur' meteorite.

Part 4 (out of print).—Points in Himalayan geology. Crystalline and metamorphic rocks of Lower Himalaya, Garhwal, and Kumaon, Section II. Iron industry of western portion of Raipur. Notes on Upper Burma. Boring exploration in Chhattisgarh coal-fields (Second notice). Pressure Metamorphism, with reference to foliation of Himalayan Gneissose Granite. Papers on Himalayan Geology and Microscopic Petrology.

Vol. XXI, 1888.

Part 1.—Annual report for 1887. Crystalline and metamorphic rocks of Lower Himalaya, Garhwal, and Kumaun, Section III. Birds'-nest of Elephant Island, Mergui Archipelago. Exploration of Jesalmer, with a view to discovery of coal. Facetted pebble from boulder bed ('speckled sandstone') of Mount Chel in Salt-range, Punjab. Nodular stones obtained off Colombo.

Part 2 (out of print).—Award of Wollaston Gold Medal, Geological Society of London, 1888. Dharwar System in South India. Igneous rocks of Raipur and Balaghat, Central Provinces. Sangar Marg and Mohowgalo coal fields, Kashmir.

Part 3 (out of print).—Manganese Iron and Manganese Ores of Jabalpur. 'The Carboniferous Glacial Period.' Pre-tertiary sedimentary formation of Simla region of Lower Himalayas.

Part 4 (out of print).—Indian fossil vertebrates. Geology of North West Himalayas. Blown-sand rock sculpture. Nummulites in Zanskar. Mica traps from Barakar and Raniganj.

Vol. XXII, 1889.

Part 1 (out of print).—Annual report for 1888. Dharwar System in South India. Wajra Karur diamonds, and M. Chaper's alleged discovery of diamonds in pegmatite. Generic position of so called Plesiosaurus Indicus. Flexible sandstone or Itacolumite, its nature, mode of occurrence in India, and cause of its flexibility. Siwalik and Narbada Chelonia.

Part 2 (out of print).—Indian Steatite. Distorted pebbles in Siwalik conglomerate. "Carboniferous Glacial Period." Notes on Dr. W. Waagen's "Carboniferous Glacial Period." Oil fields of Twingoung and Beme, Burma. Gypsum of Nehal Nadi, Kumaun. Materials for pottery in neighbourhood of Jabalpur and Umaria.

Part 3 (out of print).—Coal outcrops in Sharigh Valley, Baluchistan. Trilobites in Neobolus beds of Salt-range. Geological notes. Cherra Poonjee coal field, in Khasia Hills. Cobaltiferous Matt from Nepal. President of Geological Society of London on International Geological Congress of 1888. Tin-mining in Mergui district.

Part 4 (out of print).- Land tortoises of Siwaliks. Pelvis of a ruminant from Siwaliks. Assays from Sambhar Salt Lake in Rajputana. Manganiferous iron and Manganese Ores of Jabalpur. Palagonite bearing traps of Rajmahál hills and Deccan. Tin-smelting in Malay Peninsula. Provisional Index of Local Distribution of Important Minerals, Miscellaneous Minerals, Gem Stones and Quarry Stones in Indian Empire: Part 1.

Vol. XXIII, 1890.

Part 1 (out of print).—Annual report for 1889. Lakadong coal fields, Jaintia Hills. Pectoral and pelvic girdles and skull of Indian Dicynodonts. Vertebrate remains from Nagpur district (with description of fish skull). Crystalline and metamorphic rocks of Lower Himalayas, Garhwal and Kumaon, Section IV. Bivalves of Olive-group, Salt range. Mud-banks of Travancore coasts.

Part 2 (out of print).—Petroleum explorations in Harnai district, Baluchistan. Sapphire Mine of Kashmir. Supposed Matrix of Diamond at Wajra Karur, Madras. Sonapet Gold-field. Field notes from Shan Hills (Upper Burma). New species of Syringosphæridæ.

Part 3 (out of print).—Geology and Economic Resources of Country adjoining Sind Pishin Railway between Sharigh and Spintangi, and of country between it and Khattan. Journey through India in 1888-89, by Dr. Johannes Walther. Coal-fields of Lairungao, Maosandram, and Mao be lar kar, in the Khasi Hills. Indian Steatite. Provisional Index of Local Distribution of Important Mineral, Miscellaneous Minerals, Gem Stones, and Quarry Stones in Indian Empire.

Part 4 (out of print).—Geological sketch of Naini Tal, with remarks on natural conditions governing mountain slopes. Fossil Indian and Bones. Darjiling Coal between Lisu and Ramthi rivers. Basic Eruptive Rocks of Kadapah Area. Deep Boring at Lucknow. Coal Seam of Dore Ravine, Hazara.

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Part 3. Kumaun lakes. Celt of palæolithic type in Punjab. Palæontological notes from Karharbari and South Rewa coal-fields. Correlation of Gondwana flora with other floras. Artesian wells at Pondicherry. Salt in Rajputana. Gas and mud eruptions on Arakan coast on 12th March 1879 and in June 1843.

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Part 1. Annual report for 1880. Geology of part of Dardistan, Baltistan, and neighbouring districts. Siwalik carnivora. Siwalik group of Sub-Himalayan region. South Rewah Gondwana basin. Ferruginous beds associated with basaltic rocks of north-eastern Ulster, in relation to Indian laterite. Rajmahal plants. Travelled blocks of the Punjab. Appendix to 'Palæontological notes on lower trias of Himalayas.' Mammalian fossils from Perim Island.

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Part 1 (*out of print*).—Annual report for 1881. Geology of North-West Kashmir and Khagan. Gondwana labyrinthodonts (Siwalik and Jumna mammals). Geology of Dalhousie, North-West Himalaya. Palm leaves from (tertiary) Murree and Kasauli beds in India. Iridosmine from Noa-Dihing river, Upper Assam, and Platinum from Chutia Nagpur. On (1) copper mine near Yongri hill, Darjiling district; (2) arsenical pyrites in same neighbourhood; (3) kaolin at Darjiling. Analyses of coal and fire-clay from Makum coal-fields, Upper Assam. Experiments on coal of Pind Dadun Khan, Salt range, with reference to production of gas, made April 29th, 1881. International Congress of Bologna.

Part 2 (*out of print*).—Geology of Travancore State. Warkilli beds and reported associated deposits at Quilon, in Travancore. Siwalik and Narbada fossils. Coal-bearing rocks of Upper Rer and Mand rivers in Western Chutia Nagpur. Pench river coal-field in Chhindwara district, Central Provinces. Boring for coal at Engsein, British Burma. Sapphires in North-Western Himalaya. Eruption of mud volcanoes in Cheduba.

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Part 2 (*out of print*).—Synopsis of fossil vertebrata of India. Bijori Labyrinthodont. Skull of Hippotherium antilopinum. Iron ores, and subsidiary materials for manufacture of iron, in north-eastern part of Jabalpur district. Laterite and other manganese-ore occurring at Gosalpore, Jabalpur district. Umaria coal-field.

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Part 3 (*out of print*).—Microscopic structure of some Arvali rocks. Section along Indus from Peshawar Valley to Salt-range. Sites for boring in Raigarh-Hingir coal-field (first notice). Lignite near Raipur, Central Provinces. Turquoise mines of Nishapur, Khorassan. Fiery eruption from Minbyin mud volcano of Cheduba Island, Arakan. Langrin coal-field, South-Western Khasia Hills. Umaria coal-field.

Part 4.—Geology of part of Dangasulan pargana of British Garhwal. Mica and gneiss imbedded in gneissose granite of North West Himalayas. Geology of Takht-i-Suleiman. Smooth water anchorage on Travancore coast. Auriferous sands of Subansiri river, Pondicherry lignite, and phosphatic rocks at Musuri. Billa Surgam cave.

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Part 1.—Annual report for 1887. Crystalline and metamorphic rocks of Lower Himalaya, Garhwal and Kumaun, Section III. Birds'-nest of Elephant Island, Mergui Archipelago. Exploration of Jesalmer, with a view to discovery of coal. Facetted pebble from boulder bed ('speckled sandstone') of Mount Chel in Salt-range, Punjab. Nodular stones obtained off Colombo.

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SAMPLING OPERATIONS IN THE PENCH VALLEY COALFIELD. By G. V. HOBSON, B.SC., A.R.S.M., D.I.C., ASSOC. I.M.M., *Assistant Superintendent, Geological Survey of India* (With Plate 9)

Introduction.

WHILST making a general inspection of working methods in the Pench Valley coalfield, Chhindwara District, Central Provinces, in the year 1924, the writer took the opportunity of obtaining a number of samples from the various collieries on the field As far as time permitted a sample was taken from each working colliery because, up to that time, no precise correlation of the seams in this field had been made This correlation has been taken in hand by Dr C. S Fox in his resurvey of the coalfields of India, and in this connection the sampling results will probably be of some assistance

Previous work in this field.

The first hint as to the presence of coal in this area is contained in a description of the Trap Formation of the Sagar District by Captain S. Coulthard [1] in 1827, who in a footnote says "Between Kaisler and the Bhora Nadi there is coal. The Towa Nadi should be followed to its source, or until it is shown from whence it receives the coal fragments found in its bed."

The earliest record of the *in situ* occurrence of coal in this area is that of Lieutenant Sankey and Dr. Jerdon [2] in 1852, who report

[1] *Asiatic Researches*, Vol. XVIII, p. 72, (1833).
[2] *Quart. Journ. Geol. Soc., Lond.*, Vol. X, p. 55, (1853).

that coal crops out on the bank of a stream at the village of Chhota Burkoi in a layer about one foot thick. Mention is also made of coal in this area by the Rev. S. Hislop [1], but without giving much information as to the coal itself, and the same author discusses the age of the strata.[2]

The earliest information as to the quality of the coal is given by A. Sopwith,[3] who quotes the following average of seven samples,

	Per cent.
Fixed carbon	54·63
Volatile matter	26·21
Ash	19·16

but he gives no information as to where the samples were obtained. In 1866 W. T. Blanford [4] made an examination of the field, in which numerous outcrops of coal had by then been discovered, mainly through the perseverance of Major Ashburner, the Deputy Commissioner of Chhindwara at the time. Blanford gives details, such as thickness, dip, etc., of several exposures of coal and he names them after near-by villages. In the case of four of these, fair samples were taken over the best part of the seam by means of small fragments broken out at intervals; the analyses of these were as follows :—

Name.	Thickness of good coal.		Fixed carbon.	Volatile matter.	Ash.
	Ft.	in.	Per cent.	Per cent.	Per cent.
Chhinda (Chonda)	12	3	61	16	23
Barkui (Barkoi) about	6	0	50·3	26	23·7
Butaria (Bhutaria) about	5	10	49·3	26·5	24·2
Sirgora about	4	9	61·6	28	10·4

Chhinda and Sirgora are in the extreme easterly part of the field, in which no development has yet been done. Barkoi and

[1] *Quart. Journ. Geol. Soc., Lond.*, Vol. XI, p. 555, (1855).
[2] *Journ. Asiat. Soc. Bengal*, Vol. XXIV, p. 347, (1855).
[3] *Trans. Manchester Geol. Soc.*, Vol. VII, p. 32, (1867).
[4] *Rec., Geol. Surv. Ind.*, Vol. XV pp. 121, 137 (1882).

Bhutaria are in the centre section and the above results may be compared with the writer's samples from East Barkui and Barkui Nos. 2-3 (see page 1 8) on a moisture-free basis, bearing in mind that the above figures represent, more or less, outcrop coal.

During the period 1884 to 1886 E. A. Jones [1] made a complete examination of the coalfields of the Satpura Gondwana Basin, in which is included the Pench Valley Area. Jones gives the following analyses, with a note that they represent outcrop coal :—

Sample.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Remarks.
	Per cent.	Per cent.	Per cent.	Per cent.	
Takia (Takea) River near Datla. (Top of seam)	3·42	19·28	29·10	48·20	Does not cake. Ash light grey.
Takia River near Datla. (5 feet below top of seam.)	3·56	19·04	28·62	48·78	Ditto.
Between Datla and Badeo (Badee).	5·34	28·36	48·58	17·72	Does not cake, but sinters slightly. Ash light red.
Panara (Pannara) .	2·16	18·92	37·74	41·18	Does not cake, but sinters slightly. Ash red.

At the time of the writer's visit all work at Panara was closed down. A specimen was taken from some old stock heaps and subjected to field coking tests but gave no coke. It was not considered worth while to analyse the specimen.

The result for the coal between Datla and Badeo may be compared with the writer's figures for Badhi Colliery (see page 181) from a sample of the full seam.

Ditmas [2] deals mainly with working methods, costs, etc., but on page 131 he gives analyses of seven samples but with no details as

[1] *Mem., Geol. Surv. Ind.,* Vol. XXIV, pp. 1-58.
[2] *Trans. N. E. Inst. Min. Mech. Eng.,* Vol. LXI, Pt. 3, (1911).

to how the samples were taken, or what thickness they represent or from what locality they were derived.

Sample.	Volatile matter.	Fixed carbon.	Ash.	Evapourating power in lbs. of water.
	Per cent.	Per cent.	Per cent.	
1 . .	31·00	55·30	13·70	11·00
2 . .	28·00	61·60	10·40	11·85
3 . .	26·00	50·30	23·70	..
4 .	16·00	61·00	23·00	..
5 . .	26·50	49·30	24·20	..
6 . .	27·76	47·31	13·42	..
7 . .	28·45	47·24	11·05	..

W. Randall [1] gives the following as a typical analysis of Pench Valley coal :

	Per cent.
Moisture	6
Volatile matter	29
Fixed carbon	46
Ash	19

He classifies the coal as of the sub-bituminous non-coking type and says that it cannot be cleaned to yield coking products.

Ball and Simpson [2] in their "Coalfields of India" quote some previously published analyses but give no fresh information as to quality. The Quinquennial Review of Mineral Production for 1919-23 [3] also gives no additional information on this point.

Sampling.

The area over which the samples, herein described, were taken stretches from the Kanhan River on the west side to the Pench

[1] *Rec., Geol. Surv. Ind.*, Vol. LVI, Pt. 3, p. 244, (1925).
[2] *Mem., Geol. Surv. Ind.*, Vol. XLI, p. 95, (1913-1922).
[3] *Rec., Geol. Surv. Ind.*, Vol. LVII, (1925).

River east of the Pachmarhi-Chhindwara road. The samples were cut from a site in each pit selected to fulfill the following conditions as nearly as possible :—

Selection of site.

(i) To give a comparatively freshly cut face.
(ii) To give a full section of the seam from floor to roof.
(iii) To give as smooth a face as possible but to avoid a cleavage face.
(iv) To include in the sample no more than the average number of cleats.
(v) To avoid any very apparent irregularities in the seam.
(vi) To avoid proximity to a fault, dyke or other natural feature, likely to affect locally the quality of the coal.

The second of these conditions constitutes a difficulty in the Pench Valley, due to the fact that in most cases the roof and floor of the seam are composed of black shale very similar in appearance to much of the coal. In a good light, on the surface, it is not always easy to distinguish the shale from the coal, and in the indifferent light underground this difficulty is enhanced. Furthermore, there is no very marked dividing line between the seam and its roof and floor; the coal appears to grade into the shale both above and below. On this account it is usually a matter of opinion, to be decided by inspection, as to what actually constitutes the top and bottom of the seam. For example, in one case a site was selected for taking the sample and, on close examination for the purpose of locating the top of the seam, it was found that the miners had gradually worked up into the roof some 10 to 12 inches, leaving a corresponding thickness of coal on the floor. It is necessary that the third condition should be fulfilled, so that surface irregularities shall not be too great in proportion to the depth of the sample cut, since the harder coal, which tends to stand out, is of poorer quality.

The question of cleats is important, because the cleavage in the coal in parts of this field is quite marked, this being particularly the case in the Junnor Deo Colliery, where perfectly smooth cleavage faces are found running the full length and height of pillars. Such cleavage faces are almost invariably contaminated and iron pyrites occurs on them in more than average quantity; thus such faces must be avoided and for the same reason condition (iv) must be fulfilled.

The coal in the proximity of a fault will not yield an average sample and in the vicinity of trap dykes has in some cases been completely spoilt.

Having selected the site from which to cut the sample the following procedure was carried out. In this connection it may be mentioned that since the sampling operations were carried out in conjunction with other work it was necessary to adopt a method which would yield a satisfactory sample in the minimum of time At the selected site the working place was roughly cleaned out and where necessary roof and floor coal was cut away to give a full section of the seam. All loose coal was then cleaned back from the face and the latter thoroughly brushed down to remove dust, etc., which would affect the sample, as, on the whole, the fresh dust is the richest part of the coal. Chalk lines were then drawn on the coal face from floor to roof, the lines being from 4 to 6 inches apart, the interval depending on the thickness of the seam. A canvas sheet having been spread on the floor close up to the face the actual cutting was commenced. First an undercut was made by the writer at the extreme base of the seam by means of a steel drill with chisel edge, the drill being about two feet long and used jumper-fashion. This undercut was made the full width of the sample cut and to the desired depth and for about 4 to 6 inches up from the base. The coal so cut was caught on the ground-sheet.

Cutting the sample.

The coal here is very hard and it would have taken practically a whole day to cut one sample by means of the chisel, so the rest of the sample was cut by miners, using the ordinary miner's pick, under the supervision of the writer. With the undercut and the chalk lines it was found that the average miner made quite a satisfactory cut; the only check necessary was to make them take short, sharp strokes with the pick, as their ordinary stroke tends to make the coal fly and at times cuts a much larger piece than is desired. Whilst the cut was being made in this way an ordinary miner's basket was held in front with its edge against the coal in the cut and just below the point at which cutting was proceeding, the basket being tilted up at an angle of about 45°. In this way the miner was able to work his pick from above and the coal was cut outwards into the basket, which prevented it flying; any fine coal sifting through the basket was caught on the canvas ground-sheet. The basket

was emptied from time to time on to the sheet, to lighten it, and finally all the coal which had been cut was transferred to the sheet. The cut was then trimmed up and brushed down to remove all loose bits and dust, the final cut being from 1 to 2 inches in depth. All the coal taken having thus been put on to the ground-sheet, the four corners were gathered together and sheet and coal dumped into a miner's basket and carried back to camp. The bulk sample so obtained varied from about eighteen to twenty-four pounds in weight, according to the thickness of the seam. The total height which had been sampled was carefully measured and the result recorded.

Reduction of sample.

The bulk samples so obtained were reduced in camp, to lessen transportation charges to Calcutta, but particularly to enable the samples to be kept under uniform conditions, this being a simpler matter with small samples.

The bulk sample was weighed and then transferred to a sieve, having half-inch holes, placed over a sampling sheet of American cloth. The oversize was reduced in an iron mortar with hand pestle until the whole sample had passed through the half-inch sieve. The sample was then transferred to another sieve having quarter-inch holes, placed over a second sampling sheet. In this way an oversize was obtained of coal between $\frac{1}{2}$ inch and $\frac{1}{4}$ inch and an undersize of material $\frac{1}{4}$ inch and under. The undersize and oversize were independently coned and quartered, in the usual way, to yield a sample of one half to one quarter of the original sample, depending on the weight of the latter. The oversize was then reduced in the mortar until the whole passed through the $\frac{1}{4}$ inch sieve, mixed with the undersize sample and the whole coned and quartered to yield about half. The material, now all minus $\frac{1}{4}$ inch, was again reduced in the mortar until all passed a 20-mesh screen, this 20-mesh material being coned and quartered to yield a final sample of about one pound. The final sample was put into a specially made tin canister, sealed up and labelled. The canisters were packed into boxes holding twelve tins and despatched to Calcutta.

Sampling difficulties.

There are certain inherent difficulties in carrying out these operations in the field, which are absent when working in the laboratory or in a proper sampling room, and these have to be guarded against as far as possible.

A sampling floor was first prepared by clearing, levelling and beating down the ground for a sufficient space on which to lay the sampling sheets. In spite of this, irregularities remained or developed and these made the process of quartering satisfactorily, somewhat difficult. Wind is also apt to be troublesome as it blows away the fine dust; this would tend to upset the sample, as the fine dust probably contains a higher proportion of the clarain, which is of better quality. This dusting can be reduced by erecting temporary screens round the sampling ground. The ill effect of the dusting is probably largely counterbalanced by the fact that the clarain breaks readily when cutting the sample, falls and is all caught on the ground sheet whereas if there is any loss from flying pieces (and some slight loss on this account is almost inevitable) the material so lost will contain a higher proportion of durain.

Laboratory sampling.

In the laboratory each sample was reduced by coning and quartering to one half, and this sample was ground in a small mechanical rotary mill to pass a 100-mesh screen, the final sample being put into a wide-mouthed glass bottle with ground glass stopper. For the various tests and analyses the material was spread out and small grab samples taken from various points to give an average product.

Field coking tests.

In all cases rough field coking tests were made with some of the discarded material from the samples. This material had been ground to pass a ¼ inch sieve and was damped and packed into a small earthenware vessel, the opening of which was then plugged with clay. The container was heated in a camp fire for about one hour.

The object of making these field tests was to ascertain whether the degree of freshness of the coal had any appreciable effect on its coking properties. The results showed that whilst in some cases a poor coke was obtained in the field and not in the laboratory, on the whole if satisfactory coke was obtained in the field then coke was also obtained in the laboratory after the lapse of six or seven months.

Details of the Samples.

The following are the results obtained with the samples taken; the results have been tabulated in Table II, page 201 for ease of comparison. The data are herein given commencing with the most

easterly sample and finishing with the westerly group of samples. The numerals under each name indicate the locality as marked on the accompanying map with a figure in a black circle.

In the determination of calorific value, which was carried out in the Bomb Calorimeter, no allowance has been made for the hydrogen and moisture in the coal, so that the results include their latent heat of steam. It is to be remembered that Calories $\times 1{\cdot}8$ = B. T. U's.

Workings N. E. of Rawanwara. (19)

There are some new workings situated about half-a-mile N. E. of the village of Rawanwara which have not yet received any name. The workings consist of a vertical shaft which is reported to have cut 7 feet of coal at a depth of 45 feet, but it was impossible to check this. An incline put down near-by first crossed a trap dyke and had just cut the coal but without exposing a full section of the seam. It was impossible to get a true sample, but a basketful of coal was taken and treated in the usual way with the following result:—

Moisture		2·33 per cent.
Volatile matter		8·31 ,,
Fixed carbon		73·25 ,,
Ash		16·11 ,,
Colour of ash		Dark brown.
Coking powers	In the laboratory	Non-coking.
	In the field	Slight sintering effect.

The coal was unavoidably taken from fairly near the trap dyke above mentioned, which may be responsible for the very unusual results obtained with this coal.

Rawanwara Colliery. (5)

The Rawanwara colliery is situated west of the village of that name along the road from Rawanwara to Dongar Parasia. The main workings had been closed down recently owing to a collapse and new work commenced to the north, on the opposite bank of the stream course; it was impossible to sample this work owing to flooding. To the east of the old main workings extraction was being carried out from an adit driven in the south bank of the stream already referred to. The seam here worked is called the "two-foot-six

seam"; this was sampled over a height of 2 feet 4 inches and the analysis was as follows:—

Moisture		5·55 per cent.
Volatile matter		29·84 ,,
Fixed carbon		49·35 ,,
Ash		15·26 ,,
Colour of ash		Very light brown.
Calorific value		6,286 calories.
Coking powers	In the laboratory	Non-coking.
	In the field	Gave a very poor soft coke.

Newton's Chikhli Colliery. (14)

The Chikhli colliery is situated against the north side of the Great Indian Peninsula Railway line, at the point east of Iklehra (Eklaira) station where the line turns south, the actual colliery being on the east bank of the stream there. The seam here is in two parts with an 8-inch shale band towards the top. Originally the full thickness was taken out but, at the time of sampling, recent work was confined to the bottom or floor coal, which was accordingly sampled separately. Since the later work was confined to the floor coal it was necessary to take the sample from a point at which the full seam had been most recently taken out. The roof coal was sampled over a height of 2 feet 10 inches and the floor coal over 5 feet 9 inches, the results of the analyses being as given below. The average value for the seam as a whole is given by averaging the results in the proportion of two of floor coal to one of roof coal, this being very closely the ratio between the thickness of each part.

		Floor coal.	Roof coal.	Average.
		Per cent.	Per cent.	Per cent.
Moisture		7·93	7·22	7·69
Volatile matter		31·20	27·56	29·99
Fixed carbon		42·82	40·72	42·12
Ash		18·05	24·50	20·20
Colour of ash		Reddish brown	Buff	
Calorific value		5650	5105	5468 calories.
Coking powers	In the laboratory	Non-coking	Non-coking	*
	In the field			

Bamori Colliery. (9) The Bamori colliery is situated on the south side of the Great Indian Peninsula Railway line to the east of Iklehra (Eklaira) station, near the village of Bamori. The colliery has been opened up somewhat recently and the workings are not very extensive. The working seam here was sampled over a height of 5 feet 2 inches, the analysis being as follows:—

Moisture		8·34 per cent.
Volatile matter		30·02 ,,
Fixed carbon		45·60 ,,
Ash		16·04 ,,
Colour of ash		Light brown.
Calorific value		5,697 calories.
Coking powers	In the laboratory	Non-coking.
	In the field	Slight coking effect.

Bhajipani Colliery. (8) The Bhajipani colliery lies just south of the Great Indian Peninsula Railway line on the west side of Iklehra (Eklaira) station, at the bend of the Public Works Department road from Parasia through Barkuhi. There are two main inclines here, the more easterly being the older and having opened up a considerable area of ground: it was from this section that the sample was taken. The seam here has a 4-inch shale band near the roof and as this is sorted out by hand it was not included in the sample. The sample was cut from 1 foot 9 inches of roof coal and 5 feet 1 inch of floor coal, a total of 6 feet 10 inches, which was all put together as one sample, the analysis being as follows:—

Moisture		7·54 per cent.
Volatile matter		28·82 ,,
Fixed carbon		44·96 ,,
Ash		18·68 ,,
Colour of ash		Light brown.
Calorific value		5,894 calories.
Coking powers	In the laboratory	Non-coking.
	In the field	

Eklaira Colliery. (11) The Eklaira colliery is situated just east of the village of this name and just south of the Great Indian Peninsula Railway line. The colliery is developed from a main incline and a considerable area has been opened up. The seam here has a 3-inch shale band near the roof

and the seam is evidently the same as that worked at Bhajipani except for a slight thinning; this thinning becomes quite marked in the western workings of Eklaira. The sample was taken from 1 foot 3 inches of roof coal and 4 feet 9 inches of floor coal, a total of 6 feet, which was put together as one sample, the analysis being as follows:—

Moisture	. . . .	6·98 per cent.
Volatile matter	. . . .	28·47 ,,
Fixed carbon	. . . .	45·14 ,,
Ash	. . . .	19·41 ,,
Colour of ash	. . . .	Buff.
Calorific value	. . . .	5,668 calories.
Coking powers { In the laboratory	. . . .	Non-coking.
Coking powers { In the field	. . . . .	Slight coking effect.

It appears evident that the Eklaira, Bhajipani, Bamori, Jatchhapar and Newton's Chikhli collieries are all working the same seam. In all cases there is a well-marked shale band towards the top of the seam and a gradual thickening of the seam from west to east, as the following comparative table will show :--

TABLE 1.

	Eklaira.		Bhajipani.		Bamori.		Jatchhapar.		Newton's Chikhli.	
	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.
Coal . .	1	3	1	9	not		2	6	2	10
Shale . .	0	3	0	4	exposed		0	6	0	8
Coal . .	4	9	5	1	5	2	5	6	5	9

The distance from Eklaira to Newton's Chikhli colliery is about 2¾ miles. In addition the southerly extension of the seam is in each case cut off by faulting which brings the Motur Clays into juxtaposition with the coal measures.

The Dongar Chikhli colliery is situated on the south side of the Great Indian Peninsula Railway line about three-quarters of a mile east of Chandameta village. The colliery is divided by a fault running north-east, the south-easterly section having been opened up by means

Dongar Chikhli Colliery. (13)

of an incline. The north-westerly section, known as the "Pit side," was the first part opened up and this was done from a vertical shaft. The sample here was taken from the "Pit side" against the barrier which separates the colliery from the old Chandametta goaf. The seam was sampled over a height of 5 feet 7 inches, the analysis being as follows:—

Moisture		9·60 per cent.
Volatile matter		28·94 ,,
Fixed carbon		44·28 ,,
Ash		17·18 ,,
Colour of ash		Buff.
Calorific value		5,544 calories.
Coking powers	In the laboratory	Non-coking.
	In the field	

Chandametta Colliery. (10)

The Chandametta colliery is situated at the village of that name on the south side of the Great Indian Peninsula Railway line. This was one of the first pits opened on this field and one section has been worked out and abandoned. A second section, developed from the Wallace Pit, had nearly reached the end of its productivity. A third section, Chandametta No. 2 incline, had been recently started on the south-west side of the Wallace Pit and this section was sampled. The sample was cut over a height of 6 feet, the full seam, and the analysis was as follows:—

Moisture		7·48 per cent.
Volatile matter		31·24 ,,
Fixed carbon		44·24 ,,
Ash		17·04 ,,
Colour of ash		Brown.
Calorific value		5,688 calories.
Coking powers	In the laboratory	Non-coking.
	In the field	

Barkui (Barkuhi) Colliery. (6 & 12)

The Barkui colliery is situated just east and north of the railway station of that name on the Bengal Nagpur Railway narrow-gauge line from Chhindwara; the latest work is just south west of this station. This is one of the oldest pits on the field and is at present the largest producer. The colliery has been opened up in three units. Barkui No. 1 at the time was practically exhausted and was not sampled. Barkui

No. 2 has been almost completely developed and extraction of pillars commenced; this section was sampled at a favourable site. Barkui No. 3 was just being started to replace No. 1 and very little work had been done beyond putting down an incline and connecting this with a well. This section was also sampled, but it must be remembered that the sample taken was from very near the bottom of the incline.

The full seam in Barkui No. 2 was sampled over a height of 5 feet 4 inches. There is what is known as the "four-foot seam" overlying the main seam and when pillars are drawn some of the former seam is extracted; this does not enter into the sample, the analysis of which is given below.

The seam in Barkui No. 3 has a 4-inch shale band near the roof and as this is hand-sorted, it was not sampled. The sample was cut from 1 foot 3 inches of roof coal and 4 feet 8 inches of floor coal, a total of 5 feet 11 inches, and the whole analysed as one sample.

		Barkui No. 2.	Barkui No. 3.
Moisture		7·38 per cent.	1·68 per cent.
Volatile matter		29·98 ,,	21·98 ,,
Fixed carbon		44·52 ,,	51·62 ,,
Ash		18·12 ,,	24·72 ,,
Colour of ash		Brown	Light reddish brown.
Calorific value		5,649 calories.	6,224 calories.
Coking power	In the laboratory	Non-coking	Non-coking.
	In the field	Slight coking effect	

East Barkui Colliery. (7)

The East Barkui colliery is situated just south of the Bengal Nagpur Railway narrow-gauge line from Chhindwara, about a mile south-east of Barkuhi station, the stream here flowing along the north side of the main workings. The writer understands that the name of this colliery has been changed since his visit to Bhopal Colliery.

The main dip here had just struck trap, probably on a fault line, and a boring was being put down some 40 feet ahead to prove the extension of the coal; this is quite near the trap hills south of the colliery and it remains to be seen whether the coal runs under the trap or not.

The section of the seam here is 2 feet 6 inches of top coal and 5 feet 6 inches of bottom coal with a 6-inch shale band between; for the most part only the floor coal is taken out and this alone was

sampled, over a height of 5 feet 7 inches, the analysis being as follows :—

Moisture		1·70 per cent.
Volatile matter		15·83 „
Fixed carbon		55·94 „
Ash		26·53 „
Colour of ash		Reddish brown.
Calorific value		5,980 calories.
Coking powers	In the laboratory	Non-coking.
	In the field	

There is only a comparatively narrow strip of coal here between the watercourse, in which the seam practically outcrops, and the trap in the fault, so this may not be very representative material.

Ghogri East Colliery. (17)

The Ghogri East colliery is situated on each side of the stream flowing westwards from the forest boundary about a mile west of Ghogri village, the property being in the Dhow Reserved Forest Block No. X, and extending about half-a-mile down the stream. Work has been done here from a large number of inclines, each opening up small areas, most of which are now flooded. There are two sections, but Section A to the west end is shut down. On section B to the east end, some work was being done on the north bank of the stream on a strip of coal between this stream and the boundary of the adjoining property, which was not being worked at the time. The work here was sampled but the sample was unavoidably taken from very near to the outcrop. The full seam was sampled over a height of 5 feet 9 inches, the analysis being as follows :—

Moisture		6·10 per cent.
Volatile matter		28·22 „
Fixed carbon		41·84 „
Ash		23·84 „
Colour of ash		Reddish brown.
Calorific value		5,372 calories.
Coking powers	In the laboratory	Non-coking.
	In the field	Yielding poor soft coke.

Dhow R. F. Block No. X Colliery. (18)

The Dhow Reserved Forest Block No. X colliery appears to be known only by the name of the reserved forest block in which it is situated. The workings are located on the north and south sides of a spur about a mile due south of Ambara village at about the 2,750

contour. The northern section was the one in which most work was being done and a sample was taken there. The workings are not extensive and are traversed by a minor fault. The full seam was sampled over a height of 5 feet 5 inches, the analysis being as follows :—

Moisture		4·90 per cent.
Volatile matter		30·70 ,,
Fixed carbon		42·68 ,,
Ash		21·72 ,,
Colour of ash		Reddish brown.
Calorific value		5,638 calories.
Coking power	In the laboratory	Non-coking.
	In the field	Yielding poor soft coke.

Junnor Deo Colliery. (18)

The Junnor colliery is situated on the boundary line of the Goradevi Reserved Forest about half-a-mile due west of the village of Jinnaur. The seam in this colliery is dipping at a much steeper angle than in most of the pits on this field and the seam thickens towards the dip, which is about due north. The dip faces are now working 14 feet of coal, all of which is taken out. In most of the workings about 10 feet have been taken out, with a distinct thinning towards the outcrop. This is a pit in which it was very difficult to get a satisfactory site for sampling. Owing to the thickness of the seam, six feet of the roof coal are taken out in first mining and the floor coal is dressed out in the rear, so that none of the dip workings give a full section of the seam, and owing to the changing thickness it was not considered advisable to attempt to take a composite sample. It is in this colliery that the cleavage, already mentioned, is so marked and this fact ruled out many of the pillar faces. The best compromise possible in the circumstances was made and a sample taken over a height of 8 feet 7 inches, from roof shale to floor shale, the analysis being as follows :—

Moisture		3·76 per cent.
Volatile matter		29·80 ,,
Fixed carbon		39·96 ,,
Ash		26·48 ,,
Colour of ash		Brown.
Calorific value		5,226 calories.
Coking powers	In the laboratory	Non-coking.
	In the field	

The Badhi colliery is situated on the west bank of the stream to the east of Takia Nala between the villages of Datla and Dongaria.

Badhi Colliery. (16)

This colliery is evidently working the same seam as the north-westerly workings of Datla Colliery on the opposite bank of the stream, the Datla Chai Colliery which adjoins Badhi on the west and is divided off by a trap dyke, and Dongaria just across the Takia Nala from Datla Chai. On this account and as time did not permit of samples being taken from all four, a sample was taken from Badhi, which may be taken as representative of all four.

The seam here is thicker than in the eastern part of the field and the dip is somewhat steeper. A sample was taken over a height of 9 feet 8 inches, representing the full section of the seam. This was a case where it was difficult to decide what was actually the floor and the roof. The analysis of the sample was as follows :—

Moisture	4·56 per cent.
Volatile matter	29·84 ,,
Fixed carbon	42·46 ,,
Ash	23·14 ,,
Colour of ash	Yellowish brown.
Calorific value	5,602 calories.
Coking powers { In the laboratory / In the field	Non-coking.

The Kolia colliery is situated about half a mile west of Kolia village on the north bank of the stream flowing through the

Kolia Colliery. (4)

village. There are two inclines here which at the time were practically under water. The more easterly one was being unwatered and the seam was exposed, just above the water level, in the face of the incline It was, therefore, impossible to obtain a sample here, but with a view to seeing whether this was an easterly extension of the coking coal, which had previously been found to exist to the west of Kolia, a basketful of coal was cut from the exposed corner of the seam and treated in the usual way with the following result : —

Moisture	4·34 per cent.
Volatile matter	27·16 ,,
Fixed carbon	49·16 ,,
Ash	19·34 ,,
Colour of ash	Light brown.
Calorific value	6,194 calories.
Coking powers { In the laboratory / In the field	Fairly hard coke.

It must be remembered that this is a specimen and not a sample, and furthermore that it is outcrop coal, so that it appears probable that a true sample from the dip side would yield results closely comparable with those from the collieries to the west, indicating that this is a continuation of the same seam.

Puraina Kothideo Colliery. (2)

The Puraina Kothideo colliery lies to the north-east of Ghorawari Colliery about a mile due south of the village of Kothideo. There are two interconnected inclines here, Nos. 1 and 2, with some limited underground workings which run about 200 feet to the dip, which is northward, and are then cut off by a fault that throws the strata up, and the seam outcrops on the hillside behind the colliery. Thus there is no really satisfactory site for sampling, and a position roughly midway between the fault and the outcrop was chosen as representative of the coal here. This colliery appears to yield an unusually high percentage of slack which possibly may be due to the disturbance of the faulting. No full section of the seam was exposed and the working seam was sampled over a height of 5 feet 8 inches; this was from the floor upwards and there is said to be 8 feet of roof coal above this. The analysis of this sample was as follows:—

Moisture		1·94 per cent.
Volatile matter		27·58 ,,
Fixed carbon		51·32 ,,
Ash		19·16 ,,
Colour of ash		Brown.
Calorific value		6,371 calories.
Coking powers	In the laboratory	Yields a hard coke.
	In the field	

The general character of the coke is similar to that of Ghorawari and Kanhan, though perhaps not quite so hard.

Ghorawari Colliery. (3)

The Ghorawari colliery is situated approximately one mile south-east of the village of Ghorawari Khurd, on the west side of the main stream running between this village and Puraina. At this colliery there have been eleven inclines put down at intervals along the strike but none of them have extensive workings connected below. Inclines 1 and 2 connect to an isolated set of workings but a connection was being driven to No. 3. Nos. 3 to 7 inclines are all interconnected, Nos. 4 and 7 having been driven from two original quarries, now abandoned. Inclines 8, 9 and 10

form a third independent block of workings. The workings stretch for some 2,500 feet along the strike and for some 250 feet to the dip, so that it is impossible to get a sample of coal from a point at any great distance from the outcrop.

In this case the sample was cut from workings connected with No. 3 incline and over a height of 7 feet 10 inches. The manager states that this is the centre section of the seam, with some 6 feet of coal both in the roof and floor, but no full section of the seam is exposed. He further states that a 10 foot seam and an 8 foot seam occur below, with 10 foot and 15 foot sandstone partings between. The sample of the present working seam gave the following analysis :—

Moisture	. . . .	2·40 per cent.
Volatile matter	. . . .	28·66 ,,
Fixed carbon	. . . .	50·14 ,,
Ash	. . . .	18·80 ,,
Colour of ash	. . . .	Brown.
Calorific value	. . . .	6,348 calories.
Coking powers { In the laboratory	. . .	} Yields a hard coke.
Coking powers { In the field	. . . .	} Yields a hard coke.

A sample of the coke prepared in the laboratory was analysed with the following result :—

Moisture	. . . .	0·12 per cent.
Volatile matter	. . . .	0·84 ,,
Fixed carbon	. . . .	71·40 ,,
Ash	. . . .	27·64 ,,
Colour of ash	. . . .	Brown.

This coal yields quite a satisfactory coke both in the field and in the laboratory. The field coke was of a bright silvery colour, except in the centre, where it was rather dark in colour due to insufficient heating. The coke is hard and somewhat dense. The coal here appears to be particularly liable to spontaneous combustion, and as this may be due, in part at least, to the presence of pyrites in the coal, a specimen of the coke was tested for sulphur and found to contain 0·71 per cent.

Kanhan Colliery. (1) The Kanhan colliery is situated right on the east bank of the Kanhan river, a few hundred yards north-west of the village of Damia.

Work at the time was not in an advanced state. Some preliminary work had been done by quarrying but this had been abandoned and two inclines started on the east bank. The eastern incline had just cut the seam, whilst the western one has been carried forward

some 30 feet to 40 feet, with two strike galleries. The western of these galleries met a fault after progressing about 5 feet and was stopped; the eastern gallery has been driven for about 10 feet.

The sample was cut from the east side of the incline and as near the face as accumulated water allowed. It will be seen therefore that this sample represents coal cut from the vicinity of a fault and at no great distance from the outcrop. The incline shows about 4 feet of soft earthy coal overlying the seam, of which the floor is not exposed. The sample therefore represents the seam as at present extracted and was taken over a height of 5 feet 8 inches, the analysis being as follows:—

Moisture		2·44 per cent.
Volatile matter		30·76 ,,
Fixed carbon		49·58 ,,
Ash		17·24 ,,
Colour of ash		Light brown.
Calorific value		6,515 calories.
Coking powers	In the laboratory	Yields a hard coke.
	In the field	

The coke from this sample is similar to that from the Ghorawari coal (*q.v.*); a piece was analysed with the following result:—

Moisture	0·24 per cent.
Volatile matter	0·48 ,,
Fixed carbon	73·56 ,,
Ash	25·72 ,,
Colour of ash	Dark brown.

Coking Coal.

In view of the importance of coking coals in this country the possible extension of the above described coking coals is of considerable importance and the following information may be of interest.

The samples taken show that coking coal occurs on the east bank of the Kanhan River and at intervals to Kholiya to the east. The next sample east of this is from Badhi, which can be taken to represent Dongaria as well and which is on the whole non-coking coal.

The Panara property lies about one mile north-east of Kolia colliery and at the time all work had been stopped here. A specimen

Panara Colliery.

of coal, with which to make the field coking tests, was taken from an old stock-heap. No coke was obtained, which points to the fact that the seam worked here

is not the same as that at Kolia, Ghorawari, etc., though the test was admittedly not made on very satisfactory material. In addition to this, the roof of the seam at Panara is a massive sandstone which forms a waterfall in the stream near by, whereas the strata overlying the seam at the other collieries are soft and friable with mush coal just above the seam. This is all the information available as to the possible eastward extension of the coking coal. Turning now to the westward extension the only evidence is furnished by the Kalichapar

Kalichapar Colliery.

Colliery. This colliery is situated on the south-eastern border of the village of this name, there being two villages with the same name of which this is the eastern one.

Work here was only in the prospecting stage, consisting of a vertical shaft 25 feet deep, which at the time was under water and being unwatered. This shaft is said to have cut 9 feet of coal, the bottom being still in coal. The man in charge stated that the dip was to the south, which is the opposite to the normal dip in this area, but the writer was told later that the shaft had been sunk on a fault and this unusual dip may be due to local disturbance. It was impossible to get a sample, but some coal was taken from a stock-heap and subjected to the field coking test, but did not yield a coke. This of course does not prove that coking coal does not exist west of the Kanhan River, but at present its presence can only be taken as not proven.

The data on which to base any estimate of the total quantity of coking coal in this area are extremely meagre and the writer makes

Estimate of Coking Coal Reserves.

the following estimate with all acknowledgment of the slender evidence upon which it is based.

The known evidence at present points to the existence of coking coal only between the Kanhan River and a point somewhat east of Kolia, though further investigation may prove a wider extension. At present it cannot be taken as proved that coking coal is continuous over this whole distance, since work between the Ghorawari colliery and Kanhan colliery appears to indicate an area of disturbed ground. Work was being done at the Hillside Colliery, about a mile east of Kanhan colliery, but at the time had not proved anything and no sample could be taken. As a conservative estimate it is proposed to take a strike extension of four miles for the coking coal, of which the eastern half yields a coke of somewhat lower quality, as

regards hardness, than the western half. The evidence as to extension towards the dip is even less satisfactory. Work at Ghorawari has been carried 250 feet towards the dip, at Kanhan only some 10 feet and in neither case has any prospecting been done, by boring, to prove the extension, as far as could be ascertained. At Puraina Kothideo the workings are cut off by a fault at 200 feet and the seam thrown upwards. This is characteristic of the area, which is traversed by a number of east and west faults continually throwing the strata up on the north side; this however appears to be accompanied by a falling-off in the quality of the coal. For the purpose of the estimate the writer proposes to take a possible extension to the dip of 750 feet, all of which would be at a reasonable working depth. As regards the thickness of the seam the information is rather better, but here again it is largely a matter of report, which it was impossible to verify. Thus at Kanhan about 6 feet of coal are exposed and an unknown depth remains in the floor. At Ghorawari the thickness of the seam is given as 20 feet; at Puraina Kalsa it is the same and at Puraina Kothideo it is 13 feet. The writer proposes to take a figure of 10 feet as an estimated thickness on which to base the calculation. Using these figures each of the two mile sections mentioned previously contain about 3,150,000 tons giving a total, of 6,300,000 tons of coking coal.

Dongaria Colliery.

The Dongaria colliery is situated between the village of that name and the Takia Nala to the east, this village being about two miles west of Jamai. Time did not allow of this colliery being sampled but there is little doubt that the pit is on the same seam as at Badhi, which may be taken as representative. After leaving the neighbourhood of this colliery the writer was asked to make coking tests on Dongaria coal, and for this purpose a cart-load of the coal was delivered at the camp, some twelve miles distant from the colliery. This coal not being a sample, a test on it would have been of little value as to the coking properties of the seam as a whole but from the Badhi sample it may be taken that the seam is non-coking coal.

A selection was made from the coal, by inspection, and this material was crushed and tested in the usual way. A coke was obtained which was quite hard, of a fairly bright silvery colour and about as dense as the Ghorawari coke. Time did not permit of, nor was the material suitable for, a series of tests to be made to determine the

proportion of the coal that will coke, but the simple experiment carried out serves to show that coking coal can be selected by inspection from this seam and probably from all other collieries in the field. A piece of the coke obtained was analysed and the analysis of the Badhi coal is repeated with this coke analysis for ease of comparison.

	Coke from Dongaria selected coal. Per cent.	Badhi sample coal. Per cent.
Moisture	2·18	4·56
Volatile matter	3·02	29·84
Fixed carbon	70·62	42·46
Ash	24·18	23·14
Colour of ash	Brown.	Yellowish brown

For purposes of comparison the tabulated statement of the analyses (pages 188-9) also shows the proximate analyses reduced to a moisture-free basis. It must however be remembered that all samples were dealt with under almost similar conditions and after reduction were kept under identical conditions, so that it appears that the moisture content of the air dried samples is a characteristic of the coals, and it will be observed that coals falling in groups according to calorific value also have closely corresponding moisture contents and fall fairly well into geographical groups. The moisture in the coals from the western end of the field is consistently low by comparison with the main central section.

Samples one to four fall into one group on the basis of their analyses and these form a geographical unit at the western end of the field. Sample five represents a seam not worked elsewhere. Samples eight to fourteen form another group both as regards analyses and geographical position. Samples six and seven appear to fall in this group as regards position but the analyses show a marked difference in ash content; this may be due to the location of the sample, which, as explained under the descriptions, was not very satisfactory in either case. Samples fifteen to nineteen represent scattered localities which the writer makes no attempt to correlate.

The localities from which the samples were taken are marked on the accompanying map (Plate 9) with the number of the sample in a circle. The sample letters in the table refer to the identification letter given in the laboratory records of the Geological Survey of India

TABLE II.

Reference Number and Letter.	Name of Colliery.	Calorific value calories (for B. T. U's. × 1·80).	PROXIMATE ANALYSES.							Colour of ash.	Coking properties, L. in lab. F. in field.		REMARKS.
			ON AIR DRIED SAMPLE.			ON MOISTURE FREE BASIS							
			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Volatile matter.	Fixed carbon.	Ash.				
			Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.				
1-T	Kanhan . .	6,515	2·44	30 76	49·56	17·24	31·53	50·80	17·67	Light brown.	L F	Hard coke .	5′ 8″ sampled.
2-U	Puraina Kothideo .	6,371	1·94	27·58	51·32	19·16	28·13	52·34	19·54	Brown	L F	Do. .	Ditto.
3-N	Ghorawari . .	6,348	2·40	28·66	50·14	18·80	29·36	51·37	19·26	Do.	L F	Do. .	7′ 10″ sampled.
4-R	Kolia . . .	6,194	4·34	27·16	49·16	19·34	28·39	51·39	20·22	Light brown.	L F	Cokes but not strongly Fairly hard coke.	Not a sample specimen only.
5-O	Rawanwara. 2′ 6″ seam.	6,286	5·55	29·84	49·35	15·26	31·59	52·25	16·16	Very light brown.	L F	Non-coking Slight coking effect.	2′ 4″ sampled.
6-L	Barkui No. 3 . .	6,224	1·68	21·98	51·62	24·72	22·36	52·50	25·04	Light reddish brown.	L F	Non-coking	5′ 4″ sampled.
7-V	East Barkui . .	5,980	1·70	15·83	55·94	26·53	16·10	56·91	26·99	Reddish brown.	L F	Do. .	5′ 7″ sampled.
8-K	Bhajipani . .	5,804	7·54	28·82	44·96	18·68	31·17	48·63	20·20	Light brown.	L F	Non-coking Some coking effect.	6′ 10″ sampled.
9-X	Bamori . . .	5,697	8·34	30·02	45·60	16·04	32·75	49·75	17·50	Do.	L F	Non-coking Very soft coke.	5′ 2″ sampled.

10-W	Chandametta .	5,688	7·48	31·24	44·24	17 04	33·77	47·82	18·42	Brown	L, F Non-coking	6′ sampled.
11-B	Eklaira . . .	5,668	6·98	28·47	45·14	19 41	30·51	48·53	20·87	Buff	L Non-coking F Very soft coke.	Do.
12-F	Barkui No. 2 . .	5,649	7·33	29·98	44·52	18·12	32·37	48·07	19·56	Brown	L, F Do. .	5′ 4″ sampled.
13-P	Dongar Chikhli .	5,544	9·60	28·94	44·28	17·18	32·14	49·18	19·08	Buff	L, F Non-coking	5′ 7″ sampled.
14	Newtons Chikhli Average.	5,468	7·69	29·99	42·12	20·20	32·49	45·63	21·88	..	..	8′ 7′ sampled.
14a-A	Newtons Chikhli Floor coal.	5,650	7·93	31·20	42·82	18·05	33·89	46·51	19·60	Reddish brown.	L, F Non-coking	5′ 9″ sampled.
14b-O	Newtons Chikhli Roof coal.	5,105	7·22	27·56	40·72	24·50	29·70	43·89	26·41	Buff	L, F Do. .	2′ 10″ sampled.
15-Z	Dhow R. F. Block No. X.	5,638	4·90	30·70	42·68	21·72	32·18	44·78	22·84	Reddish brown.	L Non-coking F Soft coke	5′ 5″ sampled.
16-M	Badhi . . .	5,602	4·56	29·84	42·46	23·14	31·26	44·49	24·25	Yellowish brown	L, F Non-coking	9′ 8″ sampled.
17-G	Gogri . . .	5,372	6·10	28·22	41·84	23·84	30·05	44·56	25·39	Reddish brown.	L Non-coking F Soft coke	5′ 9″ sampled.
18-J	Jamnor Deo . .	5,226	3·76	29·80	39·96	26·48	30·86	41·52	27·51	Brown	L, F Non-coking	8′ 7″ sampled.
19-Y	H. N. H. of Rawanwara.	..	2·33	8·31	73·25	16·11	9·72	75·00	16·49	Dark brown.	L Non-coking F Slight coking effect.	Not a sample, specimen only.

In conclusion the writer has to express his appreciation of the great assistance given to him by all colliery owners, or their representatives and managers, in the taking of the samples, and that of Mahadeo Ram, Laboratory Assistant, Geological Survey of India in the making of the various tests and analyses.

ON THE COMPOSITION OF SOME INDIAN GARNETS. BY L. LEIGH FERMOR, D.SC., O.B.E., A.R.S.M., F.G.S., *Superintendent, Geological Survey of India.* (With Plate 10.)

I. Introduction.

In 1912 it was arranged that an investigation into the chemical composition of Indian garnets should be undertaken by Mr. S. N. Godbole, M.Sc., who has since become Assistant Professor of Chemistry in the Victoria College of Science, Nagpur. I accordingly selected for him from our collection 9 specimens of Indian garnet, illustrating various modes of occurrence of this group of minerals in India. The original intention was that, on completion of the analysis of this first batch of material, a further series of specimens should be sent illustrating other modes of occurrence; pressure of work has, however, prevented Mr. Godbole from continuing his analyses.

In each analysis the constituents usual in garnet were determined, but some of the analyses totalled to a little over 96 and 97 per cent. only. It was then suggested that perhaps alkalies were present; but after a careful search Mr. Godbole failed to detect their presence, as also the presence of titania. As Mr. Godbole's duties preclude any further work on this material, these analyses have to be utilised as they stand, and, although four of them total to too small a figure, indicating either that there is some other constituent present, or that some constituent has been underestimated, yet Mr. Beckett, Principal of the College, who supervised the work, accepts the responsibility for its being careful and conscientious work, the results of which can be safely utilised. Mr. Godbole has kindly consented to my discussing his analyses from the geological and mineralogical point of view.

II. Description of Material used.

The specimens sent for analysis were examined by me before despatch and their descriptions recorded. Thin sections have been cut from duplicate material and examined under the microscope.

These descriptions with the data elicited under the microscope follow :—

J. 371. Orange-red or mahogany-red garnet from the garnet mines, Sarwar, Kishengarh State, Rajputana.

Under the microscope this garnet is practically colourless, and shows numerous inclusions of three sorts. The most abundant are minute needles arranged in several parallel sets, oriented presumably with some reference to the crystallographic habit of the mineral ; but as the specimen sectioned showed no crystal faces this relationship is not obvious. The refractive index of these needles is greater than that of garnet ; the polarisation tints range up to blue of the first order, the extinction is oblique, ranging from 15° up to 39° with reference to the long axis of the needles, the ray nearest the vertical axis being sometimes that of lesser and sometimes that of greater elasticity. The colour of these needles is very pale yellowish. The second kind of inclusion is in broader needles, polarising in first order grey. There are also a few grains of a mineral of lower refractive index than the garnet and very low birefringence and probably apatite. The above list of inclusions sounds formidable, but the total amount is exceedingly small.

I. 16. Three cut garnets from Jaipur, Rajputana. Light crimson colour.

A small cut gem was sacrificed for microscopical examination. As the slice is rather thick, the garnet is of very pale pink tint and looks almost perfectly pure. There are no cracks or signs of alteration : but there are an exceedingly few very minute doubly refracting grains.

F. 367. "Spessartite", dodecahedron from mica-schist, Kulu. Attached mica scratched off.

One rhombohedral dodecahedron was sacrificed for the preparation of a thin slice. In this the garnet is very pale pink and shows a small quantity of included black and brown oxides which would be impossible to eliminate. In addition there are a few very minute pleochroic grains of negative elongation and absorption at right angles to length. They may be brown tourmaline with the following pleochroism. O nearly colorless, E brownish ; $O > E$.

13/546. From a pegmatite dyke, Biradavole, Nellore district, Madras. General colour mahogany : orange-red to fiery red on thin edges. The garnet was trapezohedral modified by the rhomb-dodecahedron.

In thin section under the microscope this garnet is pale pink with perhaps an orange tinge. Under the low power the garnet appears pure except for a very few tiny inclusions of quartz (with colorless mica in one case). But under the high powers the garnet is seen to contain numerous minute needles arranged in thin parallel sets mainly at angles of 60°. These needles are usually so thin as to appear

opaque, but where slightly thicker they are seen to be of positive elongation and straight extinction—properties possessed by both sillimanite and rutile. As rutile is coloured and of higher refractive index than garnet, whilst sillimanite is colourless and of lower refractive index than garnet, it ought to be possible to refer these needles to one or other of these two, but I find it difficult to decide these points on such thin needles.

17/63. Trapezohedral spessartite from pegmatite cutting Gondite Series, Bichua, Chhindwara district.

Under the microscope this garnet is very pale yellowish, with perhaps an orange tinge. It contains a very little quartz and a colorless substance, mainly occupying minute cracks, which is possibly a micaceous mineral. There is also a little secondary iron-ore.

18/582. Garnet-rock from Nautan-Barampur, Ganjam district, Madras. Considerably blackened in patches: in others of light buff or crimson colour. Some pale blue apatite grains. Thought to be mangan-grandite. From Kodurite Series.

Under the microscope this is seen to be a granular rock composed mainly of practically colourless garnet (? a yellowish tinge), with a moderate amount of scattered quartz. There is much secondary iron oxide along the boundaries of the garnet grains with some black oxide as well, presumed to be an oxide of manganese.

18/912. Piece of a large trapezohedral crystal from Satak, Nagpur district, C. P. Dark yellow-brown to yellowish liver-coloured, probably partly altered: orange when fractured. From Gondite Series.

Under the microscope this garnet is light sulphur-yellow with numerous scattered tiny included grains of red hematite and of some black oxide, presumably manganese oxide. The distribution of these inclusions causes the crystal to be zoned parallel to the crystal faces. Some shells are nearly free from inclusions. These inclusions could not however be excluded from the material taken for analysis. In addition there is a large patch of microcline and one of black ore, both easily rejected.

18/482 (*233*). Spandite-rock from Kodur, Vizagapatam district, Madras. Chocolate-brown, due to secondary oxidation along boundaries. Fiery red where transparent. From the Kodurite Series.

Under the microscope this is seen to be a mono-mineralic granular aggregate of orange-yellow garnet, with black oxide along the boundaries of the grains, forming a black network and to a certain extent along cracks extending into the interior. In the medial zone of the black bands of the network there is often a thin streak of a light greyish substance. The interiors of the grains are perfectly fresh, but

traversed by a network of minute cracks. The material picked from this could not have been completely pure.

M. 1538. "Calderite" from Hazaribagh district, Chota Nagpur. Massive, brownish black to orange-brown (resin-coloured) where thin. From the metamorphic crystalline complex of Hazaribagh.

Under the microscope this rock is composed almost entirely of light brownish garnet, evidently in large crystal units, but much cracked. It is very fresh, however, except for very thin brownish fibres along some of the cracks: it contains a few light green pyroxene grains of quite large size.

In forwarding this material to Nagpur directions were given concerning the picking of the material to be actually used for analysis.

III. Methods and Results of Analysis.

In each case the material was, if necessary, picked, and in the case of 18/182 the garnet was treated with cold dilute hydrochloric acid to remove coatings and films of black oxide of manganese.

The specific gravity was in each case determined on the material used for analysis, the method of direct weighing in air and water being used for the larger material, and the specific gravity bottle for the smaller-sized material such as 18/482.

The analytical procedure followed by Mr. Godbole was as follows:—

After estimating the silica, iron and aluminium were separated from manganese, calcium, and magnesium by the usual methods. The manganese was then estimated as sulphide, the calcium precipitated as oxalate and the magnesium as phosphate. Iron and aluminium were estimated together as oxides, and the iron estimated volumetrically, so that the amount of aluminium was determined by difference.

Ferrous iron was separately estimated. Equal quantities of the mineral and calcium fluoride were treated with hydrochloric acid on a water bath in an atmosphere of inert gas (*i.e.* out of contact with air). After the reaction ferrous iron was estimated volumetrically.

Owing to the deficit in the totals of some of the analyses, attempts were made to estimate alkalies if present. But the results showed absence of alkalies.

The results of analysis are collected in the following table:—

TABLE No. I.—*Results of analysis of 9 specimens of garnet.*

Specimen No.	Sp.Gr.	SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	TOTAL.
J·371 .	3·64*	39·01	22·25	7·87	17·56	0·95	10·04	2·42	100·70
I·16 . .	4·24	39·47	22·31	2·84	29·97	0·31	3·32	1·85	100·07
F·307 .	4·09†	37·66	29·22	..	21·69	4·63	2·76	3·07	99·63
13/546 .	4·15	34·81	22·87	14·77	9·38	11·07	..	2·90	96·20
17/63 .	3·95‡	36·02	19·70	5·93	5·08	26·06	1·35	5·06	100·10
18/582 .	3·54§	38·61	17·91	8·75	3·02	26·51	2·18	1·95	98·93
18/912 .	4·13	34·73	22·46	4·51	1·63	35·30	..	0·97	99·60
18/482(233).	3·72	32·76	7·92	18·54	1·23	11·77	0·60	24·43	97·34
M·1538 .	3·73	37·43	8·30	10·86	3·85	2·89	0·81	24·40	97·63

* This result is obviously too low and is not used further. A duplicate piece of J·371 of mahogany brown colour gave G=3·93 in the Geological Survey of India laboratory, and another of purplish rose colour gave G=3·95. The former figure is used in later tables.

† Other crystals of this number gave in the Geological Survey of India laboratory results ranging from 4·11 to 4·16 (Mem., Geol. Surv. Ind., XXXVII, p. 175).

‡ Another crystal was found by me to have a specific gravity of 4·02 (*l.c.*).

§ Obviously too low: not used further.

IV. Interpretation of the Results.

In Table No. 2 these 9 analyses have been rearranged in terms of their constituent garnet molecules, amongst which it has, in one of the analyses, been necessary to assume the existence of the molecule $3FeO.Fe_2O_3.3SiO_2$. It will be seen that the total percentage of garnet molecules ranges from as high as 98·48 per cent to as low as 79·97 per cent.

The excess over the garnet molecules has been shown as sillimanite, quartz, surplus alumina and ferric oxide and, in one analysis, as lime, whilst in most cases there is a surplus of oxygen, due probably, at least in part, to the difficulty of estimating exactly the amounts of FeO and Fe_2O_3 in an insoluble silicate, but possibly in some cases to slight oxidation of the garnet. To ascertain if any of these impurities were microscopically visible, I had thin sections cut of each of these garnets (not, of course, of the pieces actually analysed), and the results of the examination of these have been given in pages 192 to 194.

A comparison of the impurities shown in table No. 2 with those noticed under the microscope is of interest. Sillimanite is shown in three analyses. I·16 is, however, too pure to contain nearly 8 per cent. of impurities, unless in solid solution, which seems improbable. F.367 contains no visible sillimanite and only a very small quantity of other inclusions. The specimen analysed must have been much less pure than that examined by me. 13/546, which should contain over 7 per cent. of sillimanite, does in fact show, under the microscope, numerous minute needles that may be either sillimanite or rutile, and also a little quartz. But the amount of inclusions cannot be nearly as high as 7 per cent.[1] Quartz in appreciable quantity should be shown by 18/582 and M.1538. Such proved to be the case. Surplus ferric oxide should be, according to the analyses, shown by four of the garnets. Of these J.371 does not show ferric oxide, but shows other inclusions.

[1] That sillimanite does actually occur inside garnet I proved to my satisfaction by examining the garnets in two thin slices of khondalite, one being Dr. T. L. Walker's original khondalite from Kalahandi (4239-15/181) of which the garnet is represented in the table on p. 200 and the other a slice of this rock (5339) from Nantan-Barampur in Ganjam, collected by myself.

TABLE No. 2.

No.	G.	Pyrope.	Almandite.	Spessartite.	Grossularite.	Andradite.	$3FeO \cdot Fe_2O_3 \cdot 3SiO_2$.	Total garnet.	SURPLUS.					TOTAL
									Sillimanite.	Quartz.	Al_2O_3.	Fe_2O_3.	O.	
J.371	3·98	35·55	54·20	2·23	6·50	..	..	98·48	..	..	0·26	1·30	0·66	100·70
L.16	4·24	11·08	75·16	0·74	4·97	..	..	91·95	4·54	3·28	..	..	0·28	100·05
F.367	4·09	9·22	50·14	10·77	9·84	..	..	79·97	19·39	0·25	..	..	..	99·61
13/546	4·15	..	52·24	27·20	7·81	..	..	87·25	7·51	..	0·10	..	1·48	96·36
17/63	3·95	4·50	17·60	60·74	11·29	2·60	..	96·73	..	..	..	3·28	0·18	100·15
18/582	..	7·28	16·38	61·80	..	5·91	3·27	94·64	..	3·68	..	..	0·59	98·88
18/912	4·13	..	10·04	82·24	2·62	..	..	94·90	..	..	2·88	1·46	0·30	99·54
233	3·72	2·31	2·85	27·45	4·87	52·65	..	90·13	..	..	..	1·95	5·24	97·64
M.1538	3·73	2·79	13·43	6·75	15·66	56·27	..	94·90	..	2·55	..	..	0·22	97·32

17/63 does show a little secondary iron-ore: 18/912 shows numerous scales of red hematite and grains of a black ore (? manganese-ore) in certain shells: whilst 18/482 shows much black oxide in the unpicked mineral. There are no visible impurities nor inclusions corresponding to the surplus alumina in 18/912 or the surplus lime in 18/482.

These discrepancies are possibly in part due to material being held in solid solution in garnet, and, in three analyses, probably to the fact that there is a deficit in the analysis.

The tendency of garnet to enclose other minerals is exemplified by the descriptions on pages 192-3, and is well-known [1]; nevertheless, in order to ascertain whether Mr. Godbole's results departed from the theoretical composition of garnet to a greater extent than usual, I selected from Dana's "System of Mineralogy" one analysis of each of the five chief species of garnet (omitting uvarovite), and recalculated them also into terms of garnet molecules. The analyses selected were as follows (omitting water, alkalies, etc.):

TABLE No. 3.

—	G.	SiO_2	Al_2O_3	Fe_2O_3	FeO.	MnO.	MgO.	CaO.	TOTAL.
Grossularite, No. 9, Vesuvius.	3·572	39·83	20·16	1·03	1·21	0·46	0·97	35·42	99·08
Pyrope, No. 6, Elie Ness.	4·124	40·92	22·45	5·46	8·11	0·46	17·85	5·04	100·29
Almandite, No. 4, Zillerthal.	4·04	39·12	21·08	6·00	27·28	0·80	..	5·76	100·04
Spessartite, No. 14, Glen Skiag.	4·125	35·99	16·22	8·64	23·27	15·24	0·47	0·40	100·23
Andradite, No 10, East Rock.	:·710	35·09	tr.	20 15	2·49	0·36	0·24	32·80	100·13

On recalculation into garnet molecules these analyses can be rearranged as follows:—

[1] Sir T. H. Holland's "On the Acicular inclusions in Indian Garnets," *Rec., Geol. Surv. Ind.*, XXIX, pp. 16-19, ( ), is of interest in this connection.

TABLE NO. 4.

—	Pyrope.	Almandite.	Spessartite.	Grossularite.	Andradite	$3FeO \cdot Fe_2O_3 \cdot 3SiO_2$.	$3MnO \cdot Fe_2O_3 \cdot 3SiO_2$.	Total Garnet.	SURPLUS. Sillimanite	Quartz.	Fe_2O_3.	CaO.	MgO	O.
Grossularite . .	3·24	2·80	1·08	81·92	3·25	..	..	92·25	..	2·92	..	3·55	..	..
Pyrope . .	59·30	23·47	1·08	10·79	3·11	..	..	97·75	..	..	2·19	..	..	0·23
Almandite . .	..	75·56	1·89	15·48	..	..	..	92·93	2·75	3·79	..	..	..	0·60
Spessartite . .	1·58	41·60	35·49	..	1·22	19·67	..	99·57	..	0·40	..	..	..	0·26
Andradite . .	..	..	..	..	86·05	6·41	0·93	93·39	..	2·07	..	4·41	0·24	..

In two of the garnets the molecule $3FeO.Fe_2O_3.3SiO_2$. again appears, as well as the molecule $3MnO.Fe_2O_3.3SiO_2$ in one case. The departures of these analyses from the theoretical composition of garnet are comparable with those of Mr. Godbole's analyses, and apparently such departures must be regarded as normal for garnet.

V. Other Analyses of Indian Garnets.

Besides the 9 analyses of garnets by Mr. Godbole the only other analyses of Indian garnets of which I am aware are two of "calderite" by Piddington and Tween,[1] and the analyses of Indian manganese-garnets by Messrs. T. R. Blyth, J. Coggin Brown, and the Imperial Institute, given in my memoir on the manganese ore deposits of India.[2] In addition the composition of the garnet in khondalite can be calculated from the analysis of this rock by Dr. T. L. Walker, assuming the iron to be in the ferrous condition.[3] These 8 analyses are as follows :—

TABLE No. 5.

—	G.	SiO_2.	Al_2O_3.	Fe_2O_3.	FeO.	MnO	MgO.	CaO.	BaO.	TOTAL.
1030 (18/871)-Chargaon.	..	34·71	8·05	8·38	n.d.	38·83	5·40	4·97	tr.	100·34
16/984—Wagora .	4·24	37·73	21·20	..	9·04	24·48	3·48	3·11	..	100·00[4]
A.219 (18/378)—Garbham.	4·02	35·24	6·48	23·90	n.d.	16·37	2·04	15·29	0·18	99·41
A.238 (18/302)—Kotakarra.	..	37·57	18·08	3·47	7·45	16·50	0·23	15·80	..	100·00[4]
A.134 (18/557)—Bolrani.	3·76	36·18	14·22	11·41	2·16	2·68	0·65	30·70	..	100·00[4]
Hazaribagh . .	3 735	37 44	6 27	19 38	5 24	tr.	1·40	30·93	..	100·66
Katkamsandi, Hazaribagh.	3·65	46·35	0·35	30·18	..	21·00	..	1·00	..	100·00[4]
15/181—Kalahandi .	..	37·74	21·24	..	34·06	..	4·01	2·95	..	100·00[4]

On calculation into terms of garnet molecules these analyses can be rearranged as follows :—

[1] See 'A Manual of the Geology of India,' Pt. IV, 'Mineralo ' by F. R. Mallet, pp. 89-90, (1887); and my discussion of calderite in *Mem., Geol. Surv. Ind.*, XXX pp. 182-186.
[2] *Mem., Geol. Surv. Ind.*, XXXVII, pp. 167-168, (1909).
[3] *Mem., Geol. Surv. Ind.*, XXXIII, Part III, p. 9, (1902).
[4] Calculated from rock analysis.

TABLE NO. 6.

No.	Pyrope.	Almandite.	Spessartite.	Grossularite.	Andradite.	$FeO \cdot Fe_2O_3 \cdot 3SiO_2$.	$3MnO \cdot Fe_2O_3 \cdot 3SiO_2$.	$3MnO \cdot Mn_2O_3 \cdot 3SiO_2$.	$3BaO \cdot Fe_2O_3 \cdot 3SiO_2$.	Total Garnet.	SURPLUS. O.	SURPLUS. Fe_2O_3.	SURPLUS. SiO_2.
1030—Chargaon . . .	18·04	..	10·98	..	15·38	..	12·30	23·25	..	96·05	0·97	5·37 (MnO)	..
16/984—Wagora . . .	11·65	22·92	57·08	8·35	..	..	..	..	..	100·00	..	..	..
A.219—Garbham . . .	6·79	..	23·13	..	46·08	5·40	16·79	..	0·48	98·67	0·23	0·61 (MnO)	..
A.283—Kotakarra . . .	0·77	17·24	38·50	32·43	11·06	..	..	..	..	100·00	..	..	..
A.134—Boirani	2·18	4·99	6·25	50·13	31·45	..	..	..	..	100·00	..	..	..
Hazaribagh	4·69	4·59	..	18·28	73·12	..	..	..	..	100·69	0·36	..	0·31
Katkamsandi	..	..	1·69	..	3·00	19·50	52·76	..	..	76·95	6·84	..	21·07
15/181 Kalahandi . . .	13·31	78·80	..	7·89	..	..	..	..	..	100·00	..	..	..

In two cases again the molecule $3FeO.Fe_2O_3.3SiO_2$, appears and in three cases the molecule $3MnO.Fe_2O_3.3SiO_2$, and in one case the molecule $3MnO.Mn_2O_3.3SiO_2$.

VI. Molecular Composition of Indian Garnets.

These eight additional analyses have been assembled in one table (No. 7) with Mr. Godbole's results, the order adopted being that of composition. Although this table contains 17 analyses it is not as comprehensive in the garnets represented as would have been the case had Mr. Godbole been able to deal with the second set of garnets as originally proposed. In particular it is defective in not containing analyses of the garnets of the Indian marbles and calciphyres, usually essonite or andradite, nor of the pink garnets of the garnet-amphibolites.

On scanning this table it will be observed that the *pyrope molecule* is present in quantity (>20%) only in one garnet, which is one of the precious garnets of Rajputana. The *almandite molecule* is present to the extent of over 20% in the first 6 garnets, of which the first 4 are derived from the crystalline schists—mica-schists and khondalite. The *spessartite molecule* occurs to the extent of over 20% in 8 garnets, of which one is from a pegmatite in the Nellore district, 6 are from the Gondite and Kodurite Series of the Central Provinces and Madras respectively, and one is from a pegmatite cutting the Gondite Series.

The *grossularite molecule* is found in quantity only in 2 garnets, both of which come from kodurites, one from Vizagapatam and one from Ganjam. The *andradite molecule* is found in quantity in five garnets, three of which come from the Kodurite Series of Madras and two from the massive garnet rocks of Hazaribagh.

In addition there are shown by these analyses to be three other molecules that must be considered, namely, $3FeO.Fe_2O_3.3SiO_2$, $3MnO.Fe_2O_3.3SiO_2$ and $3MnO.Mn_2O_3.2SiO_2$. The first of these occurs in quantity in the calderite of Hazaribagh and in small amount in two manganese-garnets from the Kodurite Series of Ganjam and Vizagapatam. It also occurs to the extent of nearly 20% in the "spessartite" garnet of Glen Skiag in Scotland. We must, it appears, accept this molecule as existing in some garnets. It requires, therefore, a name, and as the Indian locality Katkamsandi is unsuitable this garnet may perhaps be called *skiagite* after the Scottish locality.

TABLE NO. 7.

No. of specimen.	Locality.	Rock in which found.	G.	Pyrope (Py).	Almandite (Al).	Spessartite (Sp).	Grossularite (Gr).	Andradite (An).	$3FeO\ Fe_2O_3\ 3SiO_2$ (Sk).	$3MnO\ Fe_2O_3\ 3SiO_2$ (Ca).	$3MnO\ Mn_2O_3\ 3SiO_2$ (Bl).	Name adopted.	Colour.
J.371	Sarwar, Kishengarh.	Schist . .	3·98	36·10	55·04	2·26	6·60	..	..	..	..	Pyralmandite.	Orange-red.
L.16 .	Jaipur . .	Schist . .	4·24	12·05	81·74	0·30	5·41	..	..	..	..	Almandite.	Light crimson.
15·181 .	Kalahandi . .	Khondalite	..	13·31	78·[illegible]0	..	7·[illegible]9	..	..	..	..	Almandite	Red.
F.367 .	Kulu . . .	Mica-schist .	4·09 (4·11-4·16)	11·53	62·70	13·47	12·30	..	..	..	..	Mangan-almandite.	Brown-red.
13/546	Biradavole, Nellore.	Pegmatite .	4·15	..	59·87	31·18	8·95	..	..	..	..	Spalmandite.	Orange-red to fiery red.
16/984	Wagora, Chhindwara.	Gondite .	4·24[1]	11·65	22·92	57·08	8·35	..	..	..	..	Ferro-spessartite.	Cinnamon.
17/63 .	Bichua, Chhindwara.	Pegmatite in gondite.	3·95 (4·02)	4.65	18 20	62 78	11 68	2·69	..	..	..	Spessartite.	Orange-brown.
18/582	Nautan-Barampur, Ganjam.	Apatite-spessartite rock	..	7·70	17 31	65 30	..	6 24	3·45	.	..	Spessartite.	Light-buff.
18/912	Satak, Nagpur .	Gondite Series	4·13	..	10 58	86 66	2 76	..	..	..	..	Spessartite.	Yellow-brown.
A.233 .	Kotakarra, Vizagapatam.	Opalised kodurite.	..	0·77	17·24	38 50	32 43	11·06	..	..	..	Calc-spessartite.	
18/482	Kodur, Vizagapatam.	Spandite rock (Kodurite Series).	3·72	2·53	3·16	30·46	5·40	58·42	..	..	..	Spandite.	Fiery-red.
A.219 .	Garbham, Vizagapatam.	Spandite-rock	4 02	6 88	..	23·44	..	46 70	5·47	17·02 +0·49 (Ba Fe)	..	Spandite.	Rich-red.
M.1538	Hazaribagh. .	Massive garnet rock in metamorphic rocks.	3 73	2·94	14 15	7·11	16·50	59·30	..	..	..	Mangan-grandite	Brownish black to orange-brown.
..	Hazaribagh .	Do.	3·735	4·66	4·56	..	18·15	72·63	..	..	..	Andradite (grandite).	Yellow brown to black.
A.134	Bolani, Ganjam.	Opalised kodurite.	3·76[1]	2·18	4·99	6 25	50·13	36·45	..	..	..	Grandite.	Light brown.
1030 .	Chargaon, Nagpur	Gondite Series	4·15-4·2	18·78	..	17·68	..	16·01	..	12·81	34·72	Magnesia-blythite.	Orange-red to orange.
..	Katkamsandi, Hazaribagh.	Massive quartz garnet rock,	4·02[1]	..	..	2·20	..	3·90	25·34	68·56	..	Calderite (ferro-calderite).	Dark brown to black.

[1] Calculated from known analysis and specific gravity of rock.

The second molecule, $3MnO.Fe_2O_3.3SiO_2$, occurs in large quantity in the analysis of calderite from Katkamsandi in Hazaribagh. This particular analysis has always been considered open to doubt and attempts to repeat Piddington's results, represented in the table by the other two analyses of garnet from Hazaribagh by Mallet and Mr. Godbole respectively, have failed to disclose the large percentage of manganese found by Piddington. However, the existence of this molecule in one example of spandite from Garbham n the Vizagapatam district (17%) and in one example of spessartite from Chargaon in the Central Provinces (13%) is proved by the two analyses A.219 and 1030, which were by competent analysts. We must therefore accept this molecule also as present in some garnets, and the appropriate name for it seems to be *calderite,* as has previously been suggested.[1]

The third additional molecule is $3MnO.Mn_2O_3{\cdot}3SiO_2$, found only in one Indian garnet, at Chargaon in the Nagpur district, C. P. This garnet has hitherto been treated as a spessartite, but the abundant manganese is present as 18% of spessartite, 13% of calderite and 35% of $3MnO{\cdot}Mn_2O_3{\cdot}3SiO_2$, the balance being pyrope and andradite. The analysis was very carefully carried out by the late Mr. T. R. Blyth, for many years Assistant Curator to the Geological Survey of India, on very carefully picked material. Mr. Blyth was known for his accurate analytical work and we must therefore accept the result as returned by Mr. Blyth as accurate. The amount of material used in the analysis was only ½ gramme, so that it was not possible to determine the state of oxidation. Consequently the proportions of FeO, Fe_2O , MnO, and Mn_2O_3, had to be calculated on the assumption that the mineral conformed to the general garnet formula $3RO.R_2O_3{\cdot}3SiO_2$. Owing to the small amounts of alumina (8·05%) and Fe_2O_3 (8·38%), assuming all the iron as being in the ferric condition, there appears to be no escape from the $3MnO{\cdot}Mn_2O_3{\cdot}3SiO_2$ molecule. In my memoir on the manganese-ore deposits of India, already cited, no attention was directed to this point and the presence of the Mn_2O_3 molecule in the garnet did not prevent my calling it spessartite. It seems to me desirable, however, to have a name for the molecule itself, and I propose to call it *blythite* after Mr. Blyth.

[1] *Mem., Geol. Surv. Ind.*, XXXVII, p. 184.

From this table it is seen that few of the garnets contain a high enough percentage of one molecule to be designated by that name alone. If names are to be used for the remainder, compound names seem inevitable. I find it difficult to devise any systematic method of compounding these names; but I have attempted to allow for any molecule present to the extent of 20% or over, either by amalgamating two names (pyralmandite, spalmandite, spandite, grandite), or by prefixing the name of a prominent chemical constituent (mangan-almandite, ferro-spessartite, calc-spessartite, mangan-grandite).

It is possible, of course, to devise formulæ to indicate the composition of complex garnets. Thus Uhlig[1] assigns the symbol of a chemical element to each garnet, indicating the principal distinguishing chemical characteristic thereof, and builds up formulæ according to the molecular proportions of the various garnets. Pentti Eskola[2] uses formulæ indicating the atomic percentages of the elements separately in each group of isomorphous constituents, preferring this method because in an isomorphous mixture one cannot ascertain how the protoxides are combined with the sesquioxides. As, however, one speaks of the various garnet molecules as if they exist, a conformable idea of the composition of any given garnet can be given by a formula built up of symbols indicating the various garnet molecules. Using the symbols Py, Al, Sp, Gr, An, Sk, Ca, Bl, for the 8 garnet molecules considered in this paper (see table No. 7), the 17 garnets in table 7 could be represented by formulæ of which the following are examples :—

J.371 Pyralmandite	$Py_{36}Al_{55}Sp_2Gr_7$
18/912 Spessartite	$Al_{11}Sp_{87}Gr_3$
A. 219 Spandite	$Py_7Sp_{23}An_{47}Sk_5Ca_{17}$
M.1538 Mangan-grandite . . .	$Py_3Al_{14}Sp_7Gr_{16}An_{59}$
1030 Magnesia-blythite ("Spessartite")	$Py_{19}Sp_{18}An_{16}Ca_{13}Bl_{35}$

Some form of diagram may prove useful in indicating the relationships of a number of garnets. For a series of garnets containing as many as 8 molecules the diagrams used by Ford[3] and

[1] *Verh. d. Naturh. Ver. d. Rheinl. u. Westf.*, Vol. 67, pp. 307-403, (1910) : consulted in abstract in *Neues Jahrb. fur. Min. Geol. u. Pal.*, Band I, 1912, p. 22.

[2] On the Eclogites of Norway, *Videnskaps. Skrifter*, I, Mat-Naturv. Klasse, 1921, No. 8, p. 8.

[3] *Amer. Jour. Sci.*, XL, pp. 33-49, (1915).

Eskola in the papers cited are unsuitable; and instead the type of diagram constructed in Plate 10 may be used. This diagram, which is constructed on a molecular basis, is not uninstructive, as it shows a general relationship between mode of occurrence and composition. The almandite molecule is seen to be specially characteristic of the argillaceous crystalline schists, and of pegmatite: the spessartite molecule is characteristic of the Gondite and Kodurite Series and of a pegmatite cutting the Gondite Series: the andradite and grossularite molecules are abundant in some members of the Kodurite Series and the massive garnet-rocks of Hazaribagh whilst the additional molecules skiagite, calderite, and blythite occur sporadically in the Gondite Series, the Kodurite Series, and the Hazaribagh massive garnet-rocks.

VII. Specific Gravity of Indian Garnets.

In his paper on the relations existing between the chemical, optical, and other physical properties of the members of the garnet group,[1] W. E. Ford makes a study of the relationship between specific gravity and chemical composition, using 64 analyses of garnets in which the difference between the observed and calculated specific gravities does not exceed 0·1. Adopting the following specific gravity values for the pure garnets:—

Pyrope	3·510
Almandite	4·250
Spessartite	4·180
Grossularite	3·510
Andradite	3·750

Ford found that the average difference between the measured and calculated specific gravities of his 64 garnets was 0·045, or if the plus and minus signs were taken into consideration, it was only +0·002: he deduces therefrom that the values assigned above to the specific gravities of the various pure garnets must be nearly correct.

Using Ford's values for pure garnets, and taking only those Indian garnets that are free from the three new garnets, of which the specific gravity is unknown, we may compare the specific gra-

[1] *Amer. Jour. Sci.*, XL, pp. 33-49, (1915).

vity values given in Table No. 7 with those calculated from the pure garnets. This is done in the following table:—

TABLE No. 8.

	Values from Table No. 7.	Calculated from values for pure garnets.
J.371	3·98	3·90
I. 16	4·24	4·09
F.367	4·09 (4·11-4·16)	4·04
13/546	4·15	4·15
16/984	4·24	4·04
17/63	3·95(4·02)	4·06
18/912	4·13	4·17
233	3·72	3·87
M.1538	3·73	3·79
Hazaribagh	3·735	3·72
A.134	3·76	3·675

THE GEOLOGY OF THE ANDAMAN AND NICOBAR ISLANDS, WITH SPECIAL REFERENCE TO MIDDLE ANDAMAN ISLAND. BY E. R. GEE, B.A., *Assistant Superintendent, Geological Survey of India.* (With Plates 11 to 15.)

INTRODUCTION.

As a southern continuation of the longitudinal mountain ranges of western Burma, and separated from them by the Preparis Channel, the Andaman and Nicobar Archipelagoes occur as the peaks of a prominent oceanic mountain-arc extending in the Bay of Bengal from 10° 30′ north latitude as far south as 6° 45′ north latitude. From this latter point the arc continues in a south-easterly direction through the islands of Java and Sumatra.

Previous references to geology.

From a point of view of geology the Andaman Group had previously received the attention of R. D. Oldham in 1885,[1] and of G. H. Tipper during the field-season of 1904-05.[2] These authors had also visited some of the islands of the Nicobar Group. South Andaman Island, in the vicinity of Port Blair, was inspected by V. Ball[3] and Mallet.[4] The Nicobar Archipelago had also figured in the writings of Ball,[3] Rink,[5] and Hochstetter;[6] whilst Ehrenburg[7] made an examination of specimens of the Nicobar clays.

[1] *Rec., Geol. Surv. Ind.*, Vol. XVIII, pp. 135-145.

[2] *Mem., Geo. Surv. Ind.*, Vol. XXXV, Pt. 4, (1911).

[3] *Journ. As. Soc., Bengal*, XXXIX., p. 25. and p. 231.

[4] *Rec., Geol. Surv. Ind.*, Vol. XVII, Pt. 2.

[5] Die Nikobar Inseln. Kopenhagen, 1847. Translated *Selections, Records, Govt. Ind.*, LXXVII, pp. 105-153, (1870).

[6] Beitrage zur Geologie und physickalischen Geographie der Nikobar Inseln. Geologischen Beobachtungen, von Ferdinand von Hochstetter. Reise der oesterreichischen Fregatte Novara um die Erde in Jahre 1857—59. Geologische Theil iii, pp. 85-112. Wien 1866. Translated in part, *Rec., Geol. Surv. Ind.*, II, pp. 59-73, (1870). *Selections Rec. Govt. Ind.*, LXXVII, pp. 208-229, (1870).

[7] On an extensive rock-formation of Siliceous Polycystina from the Nicobar Islands. *Berlin Monatsbericht.* 1850, pp. 476-478. Abstract in *Quart. Journ. Geol. Soc.* London, Vol. VII, pt. 2., p. 118, (1851).

Period and extent of present survey.

It was during the early part of 1924 that the present survey was carried out. This survey includes—

(*a*) the geological mapping of the greater part of Middle Andaman Island;
(*b*) a visit to the islands of the Ritchie's Archipelago;
(*c*) a trip to Rutland Island, Little Andaman Island and several of the islands of the Nicobar Group.

I am especially indebted to Col. Ferrar, O.B.E., Chief Commissioner of the Andamans and Nicobars, for his kind assistance, and to members of the Forest Department for their help during the tour of Middle Andaman Island. In addition I wish to thank Major R. B. Seymour Sewell, I.M.S., Director, Zoological Survey of India, for permission to include the two photographs, forming Plates 11 and 13.

MIDDLE ANDAMAN ISLAND.

Middle Andaman, the central island of the Andaman Group, is separated from North Andaman Island by Austin Strait, and from South Andaman Island by Homfray Strait. It was not visited in 1904-05, the supposition at that time being that it was frequented by the wild Jarawa tribes. These people, however, appear nowadays to confine themselves to South Andaman Island and the few inhabitants whom we came across in the Middle Island were quite friendly.

Physical features.

The island is from 15 to 18 miles wide, and about 40 miles in length. The eastern coast-line comprises a series of rocky spurs separating stretches of sandy sea-shore often fringed by coral-reefs. The southern portion is, however, much more highly indented by creeks reaching inland for a considerable distance and lined by dense mangrove swamps.

The eastern half of the mainland includes the more prominent ridges and hills, which rise to a height of 1678 feet and 1527 feet in the peaks of Mt. Diavolo and Angelica respectively. More centrally situated is the Mt. Baker ridge which similarly follows a north to south strike. But in the northern part of the island the line of hills of which Sound Peak (1188 feet) is the highest, runs at right-angles to this general trend.

General Geology. The rocks of the island comprise two main classes :—

1. The Sedimentary Series.
2. The Serpentine Series.

They therefore correspond, as one would expect, with the strata of the north and south islands. The serpentines, being the more resistant to the action of weathering, form most of the prominent hills and ridges above noted. By their decomposition they have given rise to a very thick covering of fertile soil, and being capable of containing large quantities of water, which they give up very gradually, they furnish very dense evergreen jungles of the *gurjan* type with thick undergrowths of cane, bamboo, etc., throughout the year. The sedimentary areas are also well-wooded. In these forests the semi-deciduous *padouk* is most prominent, and the change from one area where the serpentine rocks prevail, to another where the porous sedimentaries are predominant, is very striking. Where the more impervious clays occur among the sedimentary strata, the forests are more dense and resemble those of the serpentine areas.

Vegetation.

A note on the surface drainage of the island brings out another marked difference between the serpentine and the sedimentary areas. The majority of the streams, arising in the areas where the more porous sandstones and conglomerates prevail, are either quite dry during the early months of the year, or occur as a number of separate pools linked together by a gradual seepage of water beneath the surface in the sandy beds of the watercourses Those, however, which have for their gathering-ground the serpentine highlands, preserve a continuous flow of clear water throughout the year, rendering the valleys extremely fertile and suited to cultivation.

Surface drainage.

Almost the only roadway through the island is an elephant-track used by the Forest Department to connect up Bom-lung-ta in the south with Bonnington in the extreme north-east. The inspection of the island was carried out by making successive camps along this path and working east and west as far as possible. Owing to the denseness of the jungles, in spite of the tireless efforts of the Burmans who accompanied me, progress was often very slow. By making a hurried trip along the coast the survey of the eastern portion of the island was

Communications.

roughly completed. It was hoped that a similar tour of the west coast would allow of the inspection of the western part of the island also, but this was prevented by the approach of the monsoon. From information received from members of the Forest Department who had visited that area, it seems probable that the sedimentaries prevail westwards to the coast.

For the maps of the island (2-inch to the mile, 1913-14 Survey), I am indebted to the Chief Conservator of Forests of the Andamans. The map accompanying this paper is a copy of these reduced to a scale of 1 inch to 4 miles. (Plate 12.)

Geological formations.

As above-mentioned, the following stratigraphical formations were recognised:—

1. The Eocene Sedimentaries.
2. The Serpentine Series, probably of Cretaceous age.

In addition several small outcrops of limestone, probably of a more recent age, were met with in the north of the island.

Description of strata.

1. *The Eocene Sedimentaries.*—The Eocene strata comprise the greater part of the mainland and in their lithology appear to be transitional between the predominant conglomerates of the north island and the sandstones and clays of the south, all three types being represented. The conglomerates with sandstones interbedded are characteristic of the more northern portion of the mainland whilst the clays, intercalated with the sandstones, occur more frequently in the area around Bomlung-ta and to the south. Conglomerate beds are, however, met with in the vicinity of the inliers of the older Cretaceous rocks throughout the island, being well-represented in the higher ground of the island of Porlob. They include coarse varieties in which the pebbles are well-rounded and range up to several inches in diameter, though the harder quartzitic pebbles are somewhat angular. The pebbles include chiefly white and yellow quartzites, with red jaspers and grey quartzitic sandstones. In addition small pebbles of serpentine rock occur together with volcanic types, usually of andesitic or vesicular basaltic character. The larger felspars of these volcanics are often replaced by calcite, or the rock has apparently undergone silicification, becoming somewhat cherty. The conglomerate matrix is often arenaceous, but sometimes argillaceous, of dull-green colour, and probably derived largely from the serpentines.

The conglomerates.

The sandstones.

The sandstones grade into the conglomerates and vary considerably in texture. They are usually porous and sometimes slightly micaceous. Their colour varies with the nature of the iron-content, green types being prevalent, but brown and yellow varieties, the latter often showing concentric rings due to more intensive staining with ferric oxide, occur in some parts of the island. In other cases the iron occurs in a more concretionary form. Forming the falls of many of the streams of the eastern half of the island, these sandstones are very massive. In some parts, they, together with the other sedimentaries, contain local intercalations of gypsum.

Fossils and age of the sandstone series.

Identifiable fossils were obtained from a bed of blue-grey calcareous sandstone in the northern part of the island. These were foraminifera of the type *Assilina granulosa* d'Archaic, characteristic of the Lower Eocene beds of Sind, Baluchistan, the Punjab, and Lower Burma, and denoting an horizon equivalent to the Laki beds of those regions of western India. This is the same species of *assilina* as was found by Tipper in the rocks of the southern island; it is illustrated in Plate 14, Fig. 4. The cross-section of a similar form taken from the same piece of sandstone shows from 4 to 5 whorls, the outer 3 to 4 whorls being large and not increasing very much in size after the second whorl. The septa are almost vertical, about 20 in a whorl, and the chambers about $1\frac{1}{5}$ times as high as broad. The specimens show no sign of wear, suggesting that they are not derived from pre-existing Eocene sediments. They therefore point to at least a part of these sedimentaries being of Lower Eocene age.

In the more argillaceous types of sandstones which occur associated with the clays of the Bom-lung-ta valley, occasional unidentifiable plant-fragments are to be found.

The clay beds.

The clays are usually dark or light-green in colour, together with bluish varieties. They are often considerably indurated and shaly, as exposed in the Bom lung-ta valley. Several small outcrops of coal were met with, associated with the clays and sandstones of the south. These were sometimes of lenticular form, up to 18 inches in thickness, and appeared to be of the nature of 'pockets' in the sediments. One exposure, in a western tributary of the Bom-lung-ta River to the north of the camp, suggested a more definite seam about 15 inches in thickness. The coal was of a jet black colour and of a

very friable texture, and burnt with a very smoky flame. Other less carbonised plant-remains occur in many of the clays. Occasionally calacareous concretions taking an ovoid form occur in the clay beds.

Occurrence of volcanic rock.

The occurrence of pebbles of volcanic rock in the conglomerates of the island has already been mentioned. In addition, the inclusion of material of definite volcanic origin in the sandstones is very peculiar (Plate 14, fig. 1). The sandstone grains are usually very angular and include fragments of volcanic ash and numerous fragments of angular felspars. By the decomposition of these constituents the rock becomes very porous and often friable. Such ashy sandstones are prominent in the conspicuous hill near the Yol Jig and again in the north of the island in the green sandstones around Bonnington. Similar strata also occur in other parts of the island grading into beds of volcanic tuff usually of andesitic type. Such definite volcanic ashes appear to occur at the base of the sandstone division.

More striking, however, is the occurrence of outcrops of definite volcanic rock of intermediate and basic character. In the Bom-lung-ta Creek, a short distance above Sinkar, an isolated outcrop of 'basalt' occurs in the mangrove swamp. The rock is an olivine basalt consisting of numerous lath-shaped labradorite crystals with marked flow-structure (Plate 14, fig. 3). The olivine occurs as fairly large crystals partly decomposed into calcite and serpentine. Unaltered augite is also present. These constituents together with the numerous felspar laths are included in a brown matrix in which magnetite grains are frequent. Irregular cracks in the rock are filled with spherulites of secondary mineral of a faint green colour, probably serpentine. Again, in a stream leading down the western slopes of Mount Wood, a large boulder of green vesicular volcanic rock was observed (Plate 14, fig. 2). I was unable at the time to trace this rock up the slopes to its point of origin, and had hoped to make a more detailed search from the east coast. On account of the shortness of the visit to the latter portion of the island at the end of the season the area was not re-examined. The rock is a vesicular augite andesite consisting of large porphyritic crystals of albite, some augite, and with numerous vesicles filled with secondary green celadonite(?) in the form of spherulites. The matrix is brownish-green in colour, composed partly of glass. Near the

same locality a purple breccia of angular blocks of andesitic rock outcrops in the stream-course.

The question of the stratigraphical age of these volcanics is somewhat speculative considering the number and the nature of the outcrops met with. From the fact, however, that these volcanics are frequent as pebbles in the Lower Eocene conglomerates, and, on the other hand, do not exhibit the marked alteration which the older rocks associated with the serpentine series show, it is probable that they represent a phase of volcanic activity following on the primary upheavals of these older serpentine rocks, and preceding the deposition of the Eocene sediments.

Stratigraphical position of the volcanics.

2. *The Serpentine Series.*—As previously mentioned the serpentines and their associated rocks comprise many of the hills and ridges of the central and the eastern parts of the island. These include altered basic and ultra-basic intrusions of plutonic type with occasional doleritic dykes, occurring in close association with red and green jaspers, purple porcellanic limestones, hard grey and yellow quartzites, together with occasional outcrops of calcareous gneiss.

The rocks composing these plutonic complexes vary from augite, enstatite, and bronzite peridotites, composed almost wholly of the pyroxene with olivine, to more felspathic types belonging to the gabbro group. The olivine is often largely altered to serpentine. In these rocks numerous magnetite grains are often included, together with crystals of picotite; occasionally chromite crystals were definitely observed in the rock-section. This mineral—chromite—was noted in specimens of enstatite peridotite from the Sound Peak inlier, and also from similar rocks from the serpentine area to the south of Beta-pur-dina. In many cases these rocks had suffered considerably from crushing and shearing, so that most of the primary minerals had been decomposed and largely replaced by green serpentine. A peculiar rock, apparently the result of the alteration of these ultra-basic intrusives, was seen to crop out near the indurated sandstones and shales at two points in the stream to the north of Beta-pur-dina. The rock was of a distinct glassy type, of light green colour, resembling jade though very much softer; it is talcose and could be easily ground

The plutonics.

Occurrence of chromite.

Alteration to serpentine.

into a fine white powder. It outcropped almost vertically in the water-course in a very much shattered state, separating readily along wavy planes as though these represented surfaces of flow of a very viscous liquid. Following these curved surfaces were flakes of calcite. It is probable that the junction with the sedimentaries was a faulted one and that the intense alteration of the exposed rock is the result of the crushing at the fault. Several other exposures of altered serpentinous rock were met with, but usually the connection with the sedimentaries was hidden by alluvium.

The older sedimentary beds include four prominent rock types:

The Older Sedimentaries.

(*a*) Jaspers.
(*b*) Porcellanic limestones.
(*c*) Quartzites.
(*d*) Calc-gneisses.

(*a*) *The jaspers.*—The jaspers occur as red and greenish types sometimes in the vicinity of the serpentines but also as individual outcrops among the younger sediments of Lower Tertiary age. They are often reticulated with thin veins of white quartz, and fracture conchoidally or into very angular fragments. They are quite distinct from the group of younger sedimentaries and doubtless owe their present indurated character and shattered appearance to the effects of the intrusion of the plutonics and to the subsequent earth-movements which have resulted in the folded character of the rocks of the island. They constitute the northern promontory of Porlob Island, Rosamond Point, and the coastal spur just south of Cuthbert Bay. They also crop out at several places on the mainland.

(*b*) *The limestones.*—The limestones are of a purple or dull-red porcellanic type, and occur as small inliers among the Tertiaries.

(*c*) *The quartzites.*—The quartzites are associated with the older sedimentaries in the neighbourhood of the serpentines. They are usually of a grey colour, very hard, and in section consist of a mosaic of quartz-grains of medium texture. They appear to be quite distinct from the later sandstones, their purity alone indicating them as a separate group. Occasional outcrops of yellow quartzites occur with the red jaspers. Large boulders of similar rock are seen in the Bom-lung-ta stream a short distance above the forest camp of that name.

(*d*) *The calc-gneisses.*—The calcareous gneisses occur as very occasional outcrops among the sedimentaries. Very similar to exposures seen in the southern island to the south of Port Blair and along the coast of Woodmason Bay, Rutland Island, they evidently formed a part of the pre-Tertiary land-surface on which the younger sediments were deposited. They are minutely foliated and have apparently been derived by the intense metamorphism of the highly calcified serpentine rocks, for they are seen in section to contain occasional chromite grains and inclusions of green serpentinous material. Subsequent dynamic metamorphism has resulted in the foliation of these altered calcified products.

Suggested formation of the calc gneisses.

Small outcrops of these rocks occur in the neighbourhood of the serpentines, also in the valley near the village of Bom-lung-ta, and on the coast just to the north of the Cuthbert Bay promontory.

Exposures of limestones, probably of Post-Eocene Age.

In addition to the above-described strata several small outcrops of cream and grey limestones occur in the stream-beds of the northern part of the island. Their included fossils indicate a higher horizon than that of the arenaceous sediments of the mainland. In one of the eastern tributaries of the Tugapur River, not far from the main stream, a cream-coloured limestone occurs jutting out almost horizontally from the western bank. The latter being composed largely of sandy alluvium, the relations with the arenaceous sediments of the neighbourhood are obscured. A section of this limestone when examined under the microscope shows the rock to be composed largely of small nummulites which in cross-section are somewhat globose (Plate 15, fig. 4). Together with these foraminifera are fragments of the alga, *Lithothamnion.* The latter contain conceptacles, lying near the surface of the filament, ovoid in vertical section, and opening at the surface for the dispersion of the spores. These conceptacles are of the type figured by Rothpletz[1] under the name of *Lithothamnion suganum.* Plate 15, fig. 2. As noted previously[2] a section of these nummulitic limestones strongly suggests the form *Nummulites planulatus.* It was impossible to extract a

Occurrence of Lithothamnion.

[1] Fossile Kalkalgen, *Zeit. deutsch. geol. Ges.*, Vol. XLIII, p. 295, (1891).

[2] *Rec., Geol. Surv. Ind.*, Vol. LVIII, pt. 1, p. 38, (1925).

specimen from the limestone for examination, and on reconsideration, after an examination of other limestone exposures, it seems probable that the deposit is of a more recent age than is suggested by this horizon fossil. In this limestone echinoid spines are moderately abundant, while other foraminerifera, *Nodosaria* and *Globigerina*, are occasionally included.

Again, in the eastern part of the island large boulders of greyish limestone are met with in one of the streams. This in section reveals the *Lithothamnion* fragments containing pear-shaped conceptacles arranged in a row parallel to the curved outer surface and very similar to the types figured under the name *Lithothamnion nummuliticum.* (Plate 15, fig. 1.) Although these included fossils give no very definite evidence of the horizon of the limestone, a middle or late Tertiary age is suggested by the occurrences of a very similar limestone in parts of the other islands.

Definite evidence of a late Tertiary deposit was met with in the northwestern islands of the Ritchie's Archipelago, and there is reason to suppose an incursion of the sea over some parts of the mainland at a similar period, forming a shallow-water gulf for the deposition of these limestones.

THE RITCHIE'S ARCHIPELAGO.

Position.

The Ritchie's Archipelago includes the group of islands lying from ten to fifteen miles to the east of the Middle and Southern Andaman Islands, between latitudes 12° 20′ and 11° 46′. The main islands of the group—Neill, Havelock, Nicholson, John Lawrence, Henry Lawrence, and Outram Islands, run in a general north-to-south direction, and are separated by shallow creeks, along the shores of which mangrove swamps flourish. Mangrove is also prominent along the less exposed portions of the sea-coast, separated by spurs of clays, argillaceous sandstones and shelly limestones, of which the islands are composed.

Vegetation.

Fairly thick forests prevail throughout the islands. In those parts where the impervious clays are predominant the evergreen types of jungle flourish, but in other areas where the more pervious limestones prevail, as for example on parts of Wilson Island, *padcuk* and other deciduous trees, with a less dense undergrowth, are present.

The islands had previously been visited by R. D. Oldham, who had designated the clays of this archipelago as quite distinct from the sedimentaries of the main Andaman group, and had correlated them with similar beds of the Nicobars, probably of Miocene age.

Geology of the islands visited.

In general the strata of the islands can be separated into two main groups:

A more recent division of very loosely consolidated shelly sandstones containing numerous gastropod and lamellibranch shells with occasional corals and echinoids.

A lower series of grey and greenish clays, argillaceous sandstones, white shelly limestones and occasional conglomerates—the Archipelago Group of Oldham.

The Archipelago clay series are more affected by earth-movements than the upper beds, and where these latter deposits occur they are almost horizontal or very gently inclined, whilst the clays outcrop with a general north-to-south strike and an inclination as high as 60° in some parts of the archipelago. In no case, however, has the folding been so intense as with the rocks of the mainland, so that from their general appearance and structure, these argillaceous beds signify a younger series of sediments than those of the Middle Andaman Island. The stratigraphy in greater detail of the islands visited was as follows :—

1. *Sir Hugh Rose Island.*—A visit was paid to the northern point of this most southern island of Ritchie's Archipelago. In a steep cliff-section a shelly sandstone occurs resting on the clays. This sandstone contains numerous imperfectly preserved specimens of gastropods and lamellibranchs, most of which have been dissolved and only their ferruginous casts remain, so that the rocks are very porous. Where the shell-fragments are most abundant the matrix has become consolidated to form a hard band of impure shelly limestone. Although no identifiable species could be procured from the deposit the general appearance of the fauna, and the occurrence of the rock, assign it to a more recent group of Tertiary sediments than the clays. It is obviously a shallow water deposit and corresponds with the partially consolidated shell sands of Neill Island and the ferruginous shelly sands of Outram Island to be considered later.

2. *Neill Island.*—A large portion of Neill Island is composed of the light-green and grey Archipelago clays. These are well-exposed

in the cliffs of the north-eastern part of the island where they dip northwards at an angle of 25°.

The cliffs of the western portion of the island are, however, formed of a yellow shelly sandstone, partially consolidated and weathering in honey-comb fashion. This sandstone dips north-west at 20°, in the point to the south of Cape Mears. It contains fossiliferous bands in which specimens of echinoids and lamellibranchs were obtained. The latter resembled recent species of the genus *Pecten*. The echinoids, however, gave a more definite indication of the stratigraphical horizon of the deposit. One specimen, a type of *Maretia*, is almost identical with the living species *Maretia planulatus*, now found in the Andaman seas. The specimen is slightly more flattened than the living type but this may possibly be due to crushing in the deposit. Considering the rapidity with which evolution took place in the echinoids in the Tertiary epoch the striking resemblance of this fossil type to living species is strong evidence for a fairly recent horizon for this deposit, probably as late as the Pleistocene. A fragment of the test of a *Temnopleurus* type of echinoid was also found in the deposit. The rock is obviously of shallow-water origin, and the relative uplift of this island appears to have been going on quite recently, for on parts of the coast boulders of recent coral, occurring above high-water mark, extend inland for some distance.

3. *Havelock Island.*—This is the largest of the Archipelago islands, being about 11 miles long and up to 5 miles in width. A tour was made around the coast of this island, where the best sections are available. The interior is covered with thick forests and swamp. The grey and white clays again form the greater part of this island. In several parts of the coast a level tract, a few feet above high-water level, extended inwards for a short distance. Occasional pieces of coral and recent shells were met with, suggesting possible relative uplift in recent times. On the other hand in some places these might represent a deposit of fine sand blown up by the monsoons on to the coral reefs which fringe the sea-shore at many points.

The white clays are well-exposed in the steep cliffs around the coasts. In the north-west promontory they dip north-west at 45°. Further south blue-grey sandy clays are intercalated. In the neighbourhood of Prince's Inlet and continuing to the south to Sail Rock the white and cream-coloured clays are predominant, the dip changing through north-east to east, and in the extreme

south of the island the inclination is to the south, up to 45°. Approaching these prominent white cliffs down the western coast, fine argillaceous light-green sandstones are intercalated in the clays, and a small overthrust to the south is exposed in the coastal section. In these arenaceous bands an imperfect fossil belonging to the genus *Pecten* was found. A short distance further south several types of lamellibranchs and a *Dentalium* were discovered in the clays. The shells of these specimens, though quite well preserved, were much decomposed and very fragile, so that they readily broke up when removed from the matrix. They include:

A species of *Pholas*, similar to that figured by Noetling as *P. orientalis.*

A species of *Pinna.*

A *Dentalium* similar to the type figured by Martin as *D. nangqulanense.*

Probable shallow-water origin of the Archipelago clay series.

A form of lamellibranch was also included. Although these fossils throw no very definite light on the exact horizon of the deposit in which they occur, they certainly suggest the conditions under which these argillaceous beds have been deposited. All the specimens are exceptionally thick-shelled, suggesting that the deposit is of shallow-water origin, certainly not of the deep-ooze class of sediments, as indicated by some previous writers. Again, a short distance east of Sail Rock a light-green slightly carbonaceous clay crops out with soft argillaceous sandstones, adding further evidence to the supposition of a shallow-water mode of formation for the series. Up the east coast, harder grey and green arenaceous bands stand out from the softer clays, the dip being to the south-east at an angle of from 40° to 50°.

In general structure, therefore, the rocks of the island appear to occur as an anticline with its axis running north-east to south-west, and cutting through the island between Melville Point and Prince's Inlet.

3. *Nicholson Island.*—Nicholson Island is largely surrounded by a fringe of mangrove swamp except in the extreme south-east. At this point the white clays stand out prominently. Inland the island is well forested.

4. *John Lawrence Island.*—Mangrove again hides any exposures over a considerable portion of the coast, though several cliff-sections

are observable. In the south of the island light-grey and white clays are predominant, with intercalations of fine argillaceous. slightly micaceous sandstones. The latter exhibit false-bedding at certain horizons, and dip in an easterly direction at from 8° to 10°.

5. *Henry Lawrence Island.*—Much of the eastern coast of this island is lined with mangrove swamp, but the sedimentaries stand out at several points forming white and grey cliffs in the southern and the northern parts of the island. In the extreme south the strata strike in a general north-north-west direction, the rocks occurring as a low anticline followed by a syncline to the east. The dip varies up to 12°. The rocks are of the argillaceous types previously met with. A short distance up the Kwangtung Strait a stretch of loose sand containing recent marine shells and raised about 6 feet above high-water level occurs within the shore, suggesting a relative fall of sea-level within recent times.

The exposures of the north-east of the island were also visited. The strike is here in a north-west direction, the strata cropping out in a synclinal, in which the dip varies from 20° to 45°. White clays and argillaceous sandstones occure in the north with a hard well-jointed blue-grey limestone interbedded further south.

6. *Outram Island.*—This island, situated just north of Henry Lawrence Island, consists of two north-to-south-striking ridges linked together by a low isthmus. Sandstones are here more prominent with the argillaceous strata, and in the south-western point of the island these dip north-east at 30°. In the north-west corner dark-grey clays are intercalated in the strata, which here dip south-east at a low angle.

In the extreme south-east of the island another cliff section is observed. This however comprises more recent strata than the clays and consists of a series of yellow sands with shell fragments, dipping north-east at 5°. At the south-east point of the island these beds pass into a series of alternating coarse-textured brown ferruginous shell-sands separated by harder consolidated bands of a similar nature. These harder layers are from 4 to 6 inches in thickness, whilst the softer, only partially consolidated, or unconsolidated bands range up to two feet in width. The rock contains numerous fossils, many fragmentary, but others from the softer layers can be obtained in good condition. They include corals, gastropods, and lamellibranchs, together with several small fora-

Occurrence of ferruginous shelly sands.

minifera, and a carapace of a crab. This latter fossil, Major R. B. S. Sewell has very kindly identified as belonging to the genus *Phyllyra*. In general the fauna is representative of a late Tertiary horizon. Several of the species appear to be identical with the Miocene types from Burma as figured by Dr. Noetling, whilst others were comparable with recent forms now living in Indian seas. It is suggested, therefore, that these strata are of late Tertiary, Pliocene or Pleistocene age, and correspond with the newer shallow-water deposits of Neill Island and others. They, too, were obviously deposited at no great depth.

These fossil forms include:

Corals.

Forms similar to *Paracyathus carulus*, Noet. spp. to *Ceratatrochus* and *Gastropods*.

Torinia spp.

Conus spp., similar to *C. odengensis*, Mart., but also resembling closely some recent types.

Conus spp., resembling *C. generalis* of Recent age.

Fusus, 3 spp., one species closely resembling *F. ambustus*.

Drillia spp.

Olivia spp., very similar to *Ol. australis* Duclos var.

Natica, 2 spp.

Turbonilla spp., resembling *T. rufa* from the Pliocene.

Rissoina spp.

Dentalium spp. similar to *D. tenuistriatum*.

Lamellibranchs.

Pecten, 3 spp., belonging to the sub-genus *Chlamys* and resembling the species '*javanus*' as figured by Martin.

Venus, differing slightly from *Cryptogramma scabra* as figured by Martin.

Leda virgo.

Cuspidaria spp., similar to *C. cuspidata*.

7. *Strait Island.*—This small island is situated within 3 miles of the mainland, due west of Outram Island. The rocks of the island form a steep broken anticline with the axis running north to south, and cutting through the island just to the west of the southern promontory. The strata include the white and grey clays, but with them are associated bands of shelly sandstone with ferruginised shell fragments. Conglomerates occur as a band in the south-western

sedimentaries. These latter beds, dipping at a fairly steep angle, are interesting from the fact that they contain several types of fishes' teeth. They are comparable to the Mid-Tertiary types of other areas but give little definite information concerning the age of the clay series. Several of the types belong, as one would expect, to the shark family.

8. *Colebrook's Island.*—Colebrook's Island, like Outram Island, consists of two rock ridges at the eastern and western extremities of the island, linked together by a low-lying isthmus of mangrove. The rocks of these two eastern and western promontories differ markedly from each other. In the south-eastern one the white cliffs of the Archipelago clay group of sediments are well seen. Forming the south-western point of the island, the older rocks, as met with on the mainland of Middle Andaman Island, are observed in the coastal exposures. These include the pink procellanic limestones, together with brecciated red jasper rock and conglomerates. The relations between these two series are, however, hidden by the stretch of mangrove swamp separating the two exposures.

Occurrence of tufa.

9. *Long Island.*—Long Island is situated off the south-east coast of Middle Andaman Island. Around the east coast coral beaches raised a few feet above the present sea-level stretch inland for a short distance. Further inland, forming the hilly ground, are outcrops of calcareous shelly sandstone, yellow and grey in colour, and containing numerous shell-fragments, by the partial solution of which the rock has become consolidated but remains porous. These grade into shelly limestones. White and grey argillaceous limestones and clays also occur in the north of the island. The rocks definitely belong to the Archipelago Group of sediments. In the centre of the island, a waterfall in the stream, where calcareous sandstones are exposed, is covered with a deposit of recent tufa, which is still forming rapidly.

10. *Wilson Island.*—Wilson Island, a small island lying among the northern islands of the main Archipelago, reveals the lower grey clays and fine sandstones around the coast. Above these, forming the higher parts of the island, a white porous limestone is seen. A section of these limestones shows them to contain *Lepidocyclinæ* and fragments of algæ, probably *Lithothamnion*.

From the above investigations it seems probable that, as suggested by Oldham, the main clay series of these islands comprises strata

of Mid-Tertiary age. These, from the evidence of their included fossils, carbonaceous inclusions, sandstone and conglomerate bands in various parts of the islands, appear to be definitely of shallow water origin, or formed at only a moderate depth. It is suggested that they were laid down in the seaward extension of the gulf which, stretching northwards into Lower Burma, resulted in the estuarine formations of that area during Miocene times. Following the formation of the clays and their associated sandstones, the foraminiferal limestones as seen in Wilson Island, and the shelly limestones of Long Island, were deposited; and at a later period the shelly sandstones and unconsolidated sands, as exposed in the southern islands of the group and again in Outram Island, were laid down in the shallow coastal seas. As a result of a quite recent relative uplift of the land, these late deposits were raised above sea-level to form the cliffs of the islands as indicated.

RUTLAND ISLAND, THE CINQUE ISLANDS, AND LITTLE ANDAMAN ISLAND, ETC.

Sandstones of the north of Rutland Island.

Rutland Island.—The greater part of Rutland Island is composed of the rocks of the igneous series. Serpentine rocks predominate, while veined jaspers and grey quartzites, together with the foliated calc-gneiss, also crop out occasionally. In the coastal section just north of Woodmason Bay on the west coast sandstones and shales occur and extend throughout the north-western portion of the island as far as the promontory named Norman Town. These sandstones, etc., resemble representatives of the Port Blair series of Lower Tertiary sediments. In this northern part of the island they occur as an anticline followed by a syncline in the extreme north-west with an axis running north-east to south-west. The dip varies from 30° to 50°. The rocks are mainly sandstones, slightly micaceous, and blue-grey or yellow in colour. In them bands of bedded mudstones are intercalated.

Several islands of the Labyrynth Archipelago were visited; Jolly Boys Island, Malay Tapu, and Hobday Island. In these islands similar sandstones predominate, together with bands of grey clays, the strata being thrown into a series of folds striking north-to-south. This structure is well exposed in the cliffs of Malay Tapu.

A visit was also paid to the two small islands, the Twins, to the west of Rutland Island. With outcrops of the veined plutonics and their associated rocks, the coast also shows evidence of recent relative elevation of the land in the occurrence of a sandy beach about 6 feet above high tide, and again in the presence of a recent pebble conglomerate similarly raised above the present high-tide level, and fringing the coast of the north-western part of the western island.

Evidence of recent relative uplift of the land.

The Cinque Islands.—The rocks of the Cinque islands comprise the older serpentine series, mainly altered peridotites in which one type rich in bronzite stands out prominently. Associated with these altered plutonics are occasional grey quartzites and veined volcanic rock. The latter is composed largely of minute felspar crystals and hornblende derived from augite; the felspars show definite parallel orientation.

A raised beach of fine sand with recent shell-fragments about 15 feet above high-water level occurs on the west coast of the southern island.

Little Andaman Island.— This island, lying to the south of Rutland Island, and continuing the chain into the Nicobar Group, was visited at two points, at Jackson Creek in the north-west and at Hut Bay in the south-east. The island is very low-lying and covered with thick jungle. The interior has not been surveyed. The inhabitants, though supposed to be closely allied to the hostile Jarawa tribes of South Andaman and of North Sentinel Islands, were found to be quite amicable so far as our investigations were concerned. Very few rock exposures occur on the coast, the sea-shore consisting of stretches of fine sand separated by intervening mangrove swamps.

At Jackson Creek an exposure of light-green slightly micaceous fine sandstone forms a prominent cliff on the north-east side of the bay. These sandstones are weathered in honey-comb fashion between high and low water marks, and resemble in lithology some of the Port Blair types, though on the whole of a finer variety. Bands of argillaceous sandstone are interbedded. The rocks dip gently to the east at from 15° to 18°. From the sandstones occurring just above high-water level an imperfect specimen of *Pecten*, a thin-shelled form, was obtained.

The erosion of these sandstone cliffs during recent times again points to a relative depression of the sea-level. A definite platform, evidently the result of coastal erosion, now situated about 10 feet above the present eroded coast-level, together with a small cave in these sandstones well above the present high tide mark, bear evidence of recent earth-movement.

An uplifted coastal platform.

A landing was next made at the south-west corner of Hut Bay. At this point unquestionable evidence of the occurrence of beds of recent coral rock *in situ*, above the present sea-level, was noted. Following inland a short distance, a small stream enters from the west. In the bed of this stream boulders of recent coral were abundant, and also occurred in the dense undergrowth in the vicinity of the stream. From the low-lying topography of many parts of the island it seems possible that other parts of the coast are composed of similar coral exposed by a recent relative uplift of the land.

Recent coral rock of the mainland around Hut Bay.

An interesting point was the way in which the natives of the island obtained supplies of fresh-water from the coral rock of this part of the coast. This fresh-water, forming a part of the drainage of the interior, percolating through the very porous raised coral rock, was apparently held up by the denser sea-water of the coast, and could be obtained from the larger cavities in the coral, now covered by a dense undergrowth, at a depth of about one to one-and-a-half feet, below the surface. This was at a point about 60 yards distant from the sea-coast. The level of the fresh-water, so far as one could judge, appeared to be almost the same as—perhaps a little above—the surface of the water in the bay. It is somewhat surprising to find that this water, occurring so near the coast, and in a rock in which the conditions for rapid transfusion appeared to be very favourable should remain uncontaminated.

Supplies of fresh-water from the coral rock.

A more striking example of this phenomenon was observed later during the visit to the Nicobar Islands; this is described below (p. 228).

At the northern point of Hut Bay a dissected promontory of steep cliffs of white and cream-coloured foraminiferal limestone forms a striking feature of this south-eastern coast. No definite stratification is observed, the rock surface weathering in honey-comb

Lithothamnion limestone occurrence.

form. Included in the limestone are blocks of green and brown sandstones of varying sizes, similar in type to those forming the exposures of Jackson Creek. As detached blocks within the reach of the tides, similar limestone was seen to include blocks of red jasper and veined gneiss. It seems probable that the latter boulders of more ancient rock were brought some distance by the sea, and not derived from the existing strata of the neighbourhood. The inclusion of the blocks of sandstone at least suggests a late Tertiary age for the deposit, and such is supported by its general character and nature of occurrence. A microscopical section of the limestone shows it to consist of a number of small nummulites and fragments of *Lithothamnion*, together with a reticulation of calcareous meshes. (Plate 15, fig. 4.) The *Lithothamnion* fragments show conceptacles of the *L. suganum* type (Plate 15, fig. 2). Other small foraminifera, including *Textularia*, are occasional. These foraminiferal and algal remains are embedded in a matrix of crystalline calcite. The limestone appears to represent a coastal formation formed in late Tertiary times and recently raised above sea-level.

THE NICOBAR ISLANDS.

Situation.

The Nicobar Islands continue the Andaman arc to the south, reaching a point as far south as 6° 45′ north latitude. Three main types of strata are represented in the rocks of the Archipelago. In the islands of the northern half of the group the serpentine series together with the grey Nicobar clay group of Mid-Tertiary age are dominant, whilst in the islands of Little and Great Nicobar, and of Kondul and Pulo Milo associated with this southern portion of the chain, the arenaceous facies suggesting relations to the rocks of the main Andaman Group, are observed.

Extent of visit.

During the cruise, brief visits were paid to the following islands; Kar Nicobar Island, Chaura, Kamorta, Tilanchong, Batti Malv; and in the south to Pulo Milo, Kondul, and Great Nicobar Island.

1. *Kar Nicobar Island.*—The strata of Kar Nicobar, the most northerly island of the group, include the soft grey clays of the central portion of the island and of parts of the coast, partially surrounded by a rim of raised coral of Recent age. This fringe of coral is prominent all along the east coast of the island and on it the coconut flourishes in abundance. A visit was paid to the village of Mus in the

extreme north of the island, and an inspection was also made of the coast of Sawi Bay. The raised recent coral rock and fine sand deposit form the site of the village, and in fact, of most of the settlements of the island. This is no doubt on account of the ease with which an existence is obtained from the growth of the coconut, and also from the fact that at these points fresh-water is obtainable throughout the year.

The water-supply of the village of Mus.

A note on the supply of drinkable water for the village of Mus is worth recording. Much liquor is obtained from the coconut itself, but wells of drinking-water occur in and around the village. These were all sunk in the coral rock, often at quite short distances from the sea-shore, and the supply of uncontaminated water continued without a break. Further inquiries from Mr. E. Hart, the only British representative living in the islands at that time, resulted in the following written statement: "Our water-supply is fairly abundant. Our deepest well is 27 feet and has 7 feet of water, quite fresh. My own well is 15 feet deep and has 3 to 4 feet of water. At high tide it has more, as the water rides on the tide, but it is quite fresh. Other wells are 3 to 6 feet deep. All are dug in coral rock and give excellent water. Some are only 50 yards from the sea and others well inland. We have no pumps and all wells are open; rough stones are built up to keep the sand, etc., from blowing in, or logs are laid for the same purpose."

Evidently the water, draining over the clays of the interior, passes into the porous coral rock. The flow towards the sea being continuous, sufficient time is not allowed for the sea-water to penetrate inland even at high tide to cause the contamination of the well waters, although at such short distances from the sea-shore. The only effect is to cause a rise in the water-level near the coast as the tide flows.

Along the coast of Sawi Bay, a soft shelly sandstone, and argillaceous sandstone, with bands containing numerous recent lamellibranch shells, notably *Pecten* types, occur as low cliffs. The strata dip eastwards at about 7°. A short distance further south the grey Nicobar clays come in below, and form the only type of rock exposures further south along the coast. The dip of the beds, where first visible, is at 20° in an easterly direction, but this increases as we continue along the coast, being as high as 55° near the angle of the bay.

2. *Chaura Island.*—In the cliffs of the south-eastern part of Chaura Island the light-grey Nicobar clays are well-exposed. The low-lying eastern portion of the island is however composed largely of raised coral rock, about 6 to 8 feet above high-water mark. Numerous boulders of coral, partly hidden by fine sand, occur inland.

Pottery-making.

The clays of Chaura were apparently used by the natives of that island for pottery manufacture, of which they had the monopoly among the several islands of the vicinity. Now, however, clay appears to be brought from Terressa Island, about 7 miles distant, though the monopoly of the industry apparently remains with the Chaura inhabitants.

3. *Kamorta Island.*—The south eastern portion of Kamorta Island was visited. In the cliffs of this promontory the grey Nicobar clays with intercalated bands of argillaceous sandstones and occasional pebble-beds, dip east-south-east at a low angle. The clays are well-exposed in the streams inland forming the rolling down country. They are mainly of light-grey and greenish types, though some are stained red. In one of the small valleys resting on the surface of the disintegrated clays, a thick-shelled specimen of *Voluta* was found. The fossil was water-worn and unidentifiable, but it appeared to have been derived from the clays.

The more inland parts of the island were not visited.

3. *Tilanchong and Batti Malv Islands.*—A large tract of the islands of Tilanchong and Batti Malv is composed of rocks belonging to the older Cretaceous group.

In Tilanchong Island these form a narrow irregular ridge running north-to-south and reaching a height of over 1,000 feet in Maharani Peak. To the north of Freshwater Bay, highly indurated green shales and quartzites crop out, dipping in a general easterly direction as steeply as 20°. These are seen dipping at a steeper angle further north and are associated with the red jasper rocks. Still further north less altered tuff-like sandstones, similar to some indurated Andaman types, outcrop.

Evidence of recent changes of sea-level.

Evidence of recent uplift along these coasts is seen in the coral boulders and recent shells of the vicinity of Freshwater Bay, but again, more pronouncedly in the cliff 25 feet high of cream-coloured honey-combed limestone very similar to that found at Hut Bay, Little Andaman Island; this occurs on the west coast near Novara Bay. A section of this limestone shows it to be similarly

largely comprised of *Lithothamnion* fragments and small nummulites. In the *Lithothamnion*, conceptacles of the type *L. suganum* are observed (Plate 15, fig. 2).

At Batti Malv a peridotite with bronzite is prominent among the basic intrusions.

4. *Great Nicobar, Pulo Milo, and Kondul Islands.*—The rocks of Pulo Milo and Kondul Islands consist largely of sandstones, comparable in lithology with those of Rutland Island and parts of the main Andaman Group. On the east of Pulo Milo these grey micaceous sandstones with intercalated shales dip steeply to the north-east. With the sandstones and shales of Kondul Island, thin lignite bands are intercalated.

Similar sandstones and shales are exposed in the extreme south of Great Nicobar Island, along the eastern shores of Galatea Bay. These again contain traces of carbonaceous material, and dip steeply to the east. Further north along the coast cliffs of light-green clays and argillaceous sandstones crop out. A trip was made up the Galatea River. The lower course of this river is lined with mangrove, and banks of recent alluvium occur for several miles.

Economic Geology of the Islands visited.

During the present survey several rumours were received concerning the occurrence of petroleum and of mica in the islands. Evidence of the former was no doubt the result of the misinterpretation of the phenomenon, met with in many parts of the islands, of an iridescence on the water of the more stagnant pools which occur on the sedimentaries. On examination, this was invariably found to be caused by a film of ferric oxide derived from the ferruginous matter of the sandstones and clays of the vicinity.

Occurence of gypsum.

Concerning the presence of mica in Middle Andaman, several specimens were brought to my notice, but all had been mistaken for the mineral gypsum, associated with these Eocene sediments of the islands of the Andaman Group. There appears to be no prospect whatever, at least so far as Middle Andaman is concerned, that mica will be found.

Coal.

The occurrence of coal has been mentioned previously. Those outcrops observed were of small thickness, and occurred, in at least one instance, as a lenticular pocket in the sandstones and clays.

The possibility of workable deposits of chromite in the serpentine series was also noted by Tipper. As mentioned in this report chromite was observed in several of the sections taken of these ultra-basic rocks, but no instance of its being in sufficient quantity to be of economic use was met with. It should however be mentioned, that a detailed study of these areas of intrusive peridotites was impossible in such a limited time, and also on account of the denseness of the vegetation.

Chromite.

The glassy serpentinous decomposition product, met with in the hills to the north of Beta-pur-dina, could probably be used for the manufacture of a talc-like powder, though its inaccessible position renders it at present valueless.

Some of the sandstones of Middle Andaman, notably those of the eastern part, would make fairly good building stones, though the ashy varieties, on account of their rapid weathering and friability, are of little use for such purposes. The peridotites and serpentines of the island also present possibilities of being used as serviceable building material or as ornamental stones.

Building stones.

The clays of Ritchie's Archipelago and of the Nicobars could doubtless be made use of in the manufacture of bricks and pottery, whilst the coral rock, notably the raised coral from which the saline material had been dissolved away, would provide lime for building purposes.

Use of the clays.

Is thus appears that the rocks comprising the Andaman Group are not economically important from the mineral point of view. Their chief value lies in the fertility of the soils which they produce. This is well evidenced in the luxuriance of the jungles and of the small cultivated tracts which already exist.

Fertility of the soils.

LIST OF PLATES.

PLATE 11.

A raised coral beach of the south end of Henry Lawrence Island, Ritchie's Archipelago.

PLATE 12.

Geological Map of Middle Andaman Island, Scale 1 inch to 4 miles.

PLATE 13.

Sandstone cliffs, west side of Little Andaman Island.

PLATE 14.

FIG. 1.—Ashy sandstone from the north of Middle Andaman Island.

FIG. 2.—Vesicular volcanic rock from Mt. Wood.

FIG. 3.—Basalt from the south of Middle Andaman Island.

FIG. 4.—Photograph of *Assilina granulosa*, magnified about 8 diameters.

PLATE 15.

FIG. 1.—Photomicrograph of section of late Tertiary limestone, showing *Lithothamnion* fragments including conceptacles of the *L. nummuliticum* type.

FIG. 2.—Photomicrograph of section of late Tertiary limestone, showing *Lithothamnion* thallus including conceptacles of the *L. suganum* type.

FIG. 3.—Photomicrograph of section of late Tertiary limestone, showing sections of *Lepidocyclinae*

FIG. 4.—Photomicrograph of section of late Tertiary limestone, showing *Lepidocyclinae*, *Lithothamnion*, and *Nummulites* in section

AN OCCURRENCE OF CRYPTOHALITE (AMMONIUM FLUOSILICATE). BY W. A. K. CHRISTIE, B.SC., PH. D., M. INST. M. M., *Chemist, Geological Survey of India.*

In 1925 Dr. L. L. Fermor discovered a peculiar white deposit on the ground at Bararee Colliery in the north-east section of Barari *mouza* (23° 42′; 86° 28′) in the Jharia coalfield. It overlies No. 15 seam, about 120 feet north of No. 14 incline, which was sealed up in 1912 on account of fire. At the place of the occurrence the roof of No. 15 seam is said to be about 40 feet from the surface, the seam being overlain by carbonaceous shale, which is also to some extent combustible. A much weathered mica-peridotite dyke, some four or five feet wide, crops out in the neighbourhood, dipping about 60° W. White smoke was issuing alongside the dyke and earth had been thrown on the ground to smother the fire. The white deposit usually occurred as a coating on lumps of this earth. Arborescent crystals of sulphur were also found, and in places the temperature of the ground was sufficiently high for the sulphur to be molten. The white deposit proved to be cryptohalite, a mineral previously reported only from eruptions of Vesuvius. Although the occurrence at Barari has not been produced entirely by the processes of inorganic nature—the fire in the coal seam originally being the handiwork of man—it is perhaps sufficiently unusual to deserve a brief description.

Mr. R. G. M. Bathgate, the manager of the East Indian Coal Company, kindly had a quantity of the deposit collected. The material occurs in three forms. The most striking, although it is found but rarely and in tiny crystals, is in the form of a paddle-wheel with four transparent shining blades. More common are arborescent, translucent crystals with a vitreous lustre. The most usual form is an opaque, white mass with a mammillary surface.

The transparent crystals are shaped more or less like a dart with four barbs at right angles, the length being up to 1 mm. and the breadth of the barbs up to 0·2 mm. The edges are corroded and the angles are not measurable. The crystals are uniaxial, negative. The blades are each perpendicular to the optic axis and form an interpenetration twin, whose twinning axis is perpendicular to the optic one. The refractive indices are very low: $\omega_{na}=1{\cdot}406_{\pm}{\cdot}001$ $\epsilon_{na}=1{\cdot}391_{\pm}{\cdot}003$ (immersion method in mixtures of amyl alcohol

and methyl butyrate). The material was much too scanty for more than qualitative microchemical analysis.[1]

It is easily soluble in water, corrodes glass when heated and sublimes without leaving a residue. Its solution in water gives a copious precipitate with potassium chloride and it evolves ammonia when treated with sodium hydroxide. The crystals are presumably the hexagonal form of ammonium fluosilicate prepared by C. Marignac[2] and B. Gossner.[3] The habit is peculiar in that the direction of elongation of the crystals is at right angles to the optic axis.

The isotropic material from Barari is usually in arborescent form with the edges of the crystals corroded. It is translucent, with a vitreous lustre. The specific gravity of two optically pure pieces, determined in acetylene tetrabromide and xylol was 2·004 ($\frac{25°}{25°}$). Its hardness is about 2·5. Its refractive index in sodium light is 1·369 $\pm$·001[4] (immersion method in mixtures of acetone and methyl butyrate[5]). Sufficient material for analysis was carefully picked out under the microscope. Ammonia was determined by distillation with sodium hydroxide. Hydrofluosilicic acid was precipitated as potassium fluosilicate, and in the filtrate sulphate was thrown down as barium sulphate and thereafter fluoride as calcium fluoride.

NH_4		20·43
SiF_6		78·87
F		0·07
SO_4		0·06
Cl		trace
Moisture		0·30
Insoluble in water	SiO_2	0·10
	Fe_2O_3	0·05
		99·88

The calculated percentages of NH and SiF_6 in $(NH_4)_2$ SiF_6 are 20·25 and 79·75.

[1] Most conveniently by F. Emich's capillary tube-centrifuge methods. c.f. *Mikrochemisches Praktikum*. Munich (1924).

[2] *Ann. Chim.*, Sér. 3, LX, (1860), 301.

[3] *Zeits. f. Kryst*, XXXVIII (1904), 149.

[4] H. Topsöe and C. Christiansen (*Kjöbenhavn, Dansk. Vid. Selsk. Skr.*, IX (1873), (643) found 1·3696 for the pure salt.

[5] When using volatile liquids it is convenient to have the substance in a very small stoppered bottle with plane faces, such as is used for absorption spectra work. This is completely filled with the mixture, so that no change in its concentration can occur during the determination.

The presence of ammonium fluosilicate in a sublimate from the eruption of Vesuvius in 1850 was deduced by A. Scacci[1] from an analysis of material consisting mainly of ammonium chloride. He named the mineral "criptoalite" as it was hidden in sal ammoniac. The determination was qualitatively confirmed by F. Zambonini,[2] who isolated the mineral, showed that it was isotropic and determined its specific gravity (between 1·90 and 2·08).

The commonest mode of occurrence of ammonium fluosilicate at Barari is as irregularly shaped lumps, usually with a mammillary surface, white, opaque, with a hardness of about 1. This consists of a mixture of the salt with silica. Analysis of picked specimens showed 10·24 per cent. of free silica and 17·98 per cent. of ammonium, corresponding fairly closely with the amount (18·17 per cent.) which should be present were the remainder of the substance pure ammonium fluosilicate. It seems amorphous, but, considering its composition, its apparent lack of crystalline structure may be illusory.

The fluorine of the cryptohalite comes presumably from apatite in the mica-peridotite dyke, through which the gases from the burning coal seam pass. A specimen, kindly supplied by Mr. Bathgate from a dyke in the interior of the mine, contained fluorine in abundance. The decomposing agent may be sulphur dioxide (the coal contains sulphur and sublimed sulphur accompanies the cryptohalite). Fluorite is easily decomposed by sulphur dioxide, apatite with more difficulty. Powdered fluor-apatite was heated to about 800°C in the middle of a long platinum tube shaped like a "churchwarden" pipe, immediately over the bowl of which was a flask in which water circulated. A current of moist sulphur dioxide was passed through the tube. In two hours sufficient hydrofluoric acid had been evolved to etch distinctly characters written on the waxed bottom of the flask. Silicates are of course present in profusion in the dyke, so that silicon fluoride would be available for the formation of ammonium fluosilicate from ammonia derived from the coal. Ammonium fluosilicate sublimes unchanged and in the presence of a slight excess

[1] *Napoli, Acc. Atti*, VI (1875), 35-37. Figures 12 and 15, attached to this paper, illustrating a frequent habit of small crystals of sal ammoniac from the lava of 1868, are rather like the interpenetration twins of cryptohalite described above (p. 233), and Scacci had difficulty in interpreting them as cubic. The sublimates of 1868 are reported by him to contain fluorine more frequently than those of 1850. Such crystals are unfortunately absent in the specimen of sal ammoniac, from the eruption of 1868, in the collection of the Geological Survey of India.

[2] *Napoli, Acc. Atti*, Ser. 2, XIV (1910), No. 6, 53-54,

of ammonia, might produce the opaque, white nodules of cryptohalite and silica which form the greater part of the deposit.

$(NH_4)_2SiF_6 + 4NH_3 + 2H_2O = 6NH_4F + SiO_2$[1].

The isotropic and nearly pure cryptohalite is usually found growing out of these impure nodules and has probably been formed by recrystallisation from solution in rain. The formation of the arborescent isotropic crystals can be successfully imitated by repeatedly moistening a nodule and allowing the water to evaporate. The uniaxial crystals were probably also formed by recrystallisation from aqueous solution. When some of the isotropic material was dissolved in water and allowed to recrystallise at 25°C. several small uniaxial negative crystals formed round the edges of the dish, the rest of the material crystallising with a cubic habit. The two forms can crystallise together; C. Marignac[2] obtained both on evaporating a pure solution of ammonium fluosilicate.

[1] According to this equation one might expect a large percentage of ammonium fluoride in these nodules (there being over 10 per cent. of free silica), whereas the amount of fluorine present as fluoride is a small fraction of 1 per cent. The ammonium fluoride, however, may have been eliminated at the time of its formation, as it sublimes at a much lower temperature than ammonium fluosilicate.

[2] *Ann. Chim.*, Sér. 3, LX (1860), 301.

REMARKS ON CARTER'S GENUS *CONULITES-DICTYOCONOIDES* NUTTALL WITH DESCRIPTIONS OF SOME NEW SPECIES FROM THE EOCENE OF NORTH-WEST INDIA. BY MAJOR L. M. DAVIES, R.A., F.G.S. (With Plates 16 to 20.)

Introduction.

In 1861 Carter created the genus *Conulites*[1] to receive certain Foraminifera, sent to him by Dr. Cook[2] from India, which could not in his opinion be included in the genus *Orbitolina* (d'Orbigny, 1847).[3] He seems also to have taken it for granted that these forms could not be included in Williamson's genus *Patellina* (1858),[4] which had been created to describe certain recent Foraminifera of Great Britain.

In 1862, however, Carpenter collected these three genera into one, adopting Williamson's name *Patellina* for the whole.[5] In my opinion this was unfortunate. It seems to me that the differences between these three types are far too great to be thus regarded as merely specific, and Carpenter made a mistake in abolishing two of the three original genera. Nevertheless, as he still retained the original generic distinctions in the form of specific ones, it was at least still possible to indicate the *structure* of new forms by describing them as " varieties " of one or another of Carpenter's three " species ".

Later on, however, it was emphasised that certain forms within this broadened " Patellina " group had arenaceous or sub-arenace-

[1] " Further Observations on the Structure of Foraminifera, and on the larger Fossilised Forms of Scinde, &c., including a new Genus and Species," by H. J. Carter, F.R.S. (*Annals and Magazine of Natural History*, 3rd Series, Vol. VIII, pages 309, 331, 457-458 and Pl. XV, fig. 7.)

[2] Dr. Cook, of the Bombay Army, had been Medical Officer to the British Agency at Kelat.

[3] In his *Cours Élémentaire de Palaeontologie*, 1851, pages 193-194, d'Orbigny defines *Orbitolina* as "*Orbitolites* à cotes inégaux : l'un, convexe, encroute, à lignes concentriques ; l'autre, concave, non-encroute, montrant des loges nombreuses, par lignes obliques sur le cote, au pourtour." Further examination of his geno-syntypes has shown that this definition has to be amplified, as, *e.g.*, was done by Carter.

[4] Ray Society. *On the Recent Foraminifera of Great Britain*, pages 46—47, and figs. 86—89 (reproduced as Fig. 11 below). By Wm. C. Williamson, F.R.S.

[5] Ray Society. *Introduction to the Study of the Foraminifera*, pages 229—235 Plate XIII, figs. 16, 17, and figs. XXXVII and XXXVIII (reproduced as Figs. 12, 10, and 9 below). By Wm. B. Carpenter, M.D., F.R.S.

ous tests, while others were purely calcareous; so as Carpenter had already minimised the importance of the structural distinctions by reducing them from generic to merely specific grade, the way was opened for what appears to be an undue emphasis laid upon the chemical *composition* of the test, to the ignoring of physical *structure*. As things are at present, the essential differences of structure, which three distinct genera were originally created to express, are often overlooked in favour of the importance attached to slight differences in the chemical composition of the tests.[1] Nor is this all, for the impossibility of retaining all these types within a single genus has led to re-subdivisions of the group being made, and we find that old generic names are now apt to reappear in impossible connections. Thus Chapman first described certain new forms, which he found near Cairo, as "*Patellina aegyptiensis*";[2] but afterwards, apparently because he found them to be sub-arenaceous, he referred to them as "*Conulites aegyptiensis*"[3]. And yet his own photographs of the form[4] show that it can be neither the one nor the other (in the original senses of those genera) since it has the subdivided cortical chambers found among the *Orbitolinae* alone[5] Chapman's formal definition of "Conulites", too, would actually exclude the very species (*cooki*) which the genus "Conulites" was originally created to accommodate[6] This seems to be

[1] Thus Chapman actually puts into entirely different families (Lituolidae and Rotalidae) forms which he admits "represent the same morphological species of organism" (*The Foraminifera*, cf. pp. 65 66 and 135). This seems to be manifestly wrong, and it is easier to believe that the compositon of the test varied in closely allied forms, than that morphologically very similar types should be placed far apart on the mere grounds of the chemical composition of the test. Dr. Pilgrim has very kindly drawn my attention to the fact that Ch. Schlumberger and H. Douvillé agree to this, in their paper "Sur Deux Foraminifères Éocènes" (*Bull. Soc., Géol. de France*, 4th Ser., V, 1905, pp. 291- 304). They point out that the composition of the test should be treated as a secondary, not a primary character, since it appears to vary with the materials available to the organism for the construction of its supporting and protecting walls.

[2] *Geological Magazine*, Decade IV, Vol. VII, 1900, pages 3, 10-14, and Plate II, figs. 1--3.

[3] *The Foraminifera*, 1902, p. 157. By F. Chapman, A.L.S., F.R.M.S.

[4] *Ibid.*, p. 275, fig. 36: also the figures in the *Geological Magazine*. In the latter (p. 12) Chapman himself noted that *aegyptiensis* had subdivided cortical chambers, while *cooki* had not.

[5] Or *Orbitolininae*, since I am using the term *Orbitolinae* throughout my article above as representing the sub family rather than the genus. Chapman's *aegyptiensis* is now commonly regarded as belonging to Blankenhorn's genus *Dictyoconus*, which belongs to the *Orbitolina* group.

[6] *The Foraminifera*, p. 156---157. It is strange that he makes the subdivision of its cortical chambers a generic feature of *Conulites*. Even Carpenter had been impressed by the absence of any such feature in *cooki* (op. cit., p. 234).

manifestly wrong. If a generic name is to be retained, it should surely be either in order to express the characters which it was originally created to express, or at least to express some other characters peculiar to the specimens for which the genus was created. The new definition of the genus should not exclude its own original type-form.

Finally Zittel (1913) recognises the old genus *Orbitolina*, whose structure he describes very clearly;[1] but he unfortunately makes the siliceous composition of the test a feature not only of the genus but of the sub-family, and gives no indication as to how those forms are to be placed which exhibit an identical structure in a calcareous test. He somewhat significantly removes Williamson's *Patellina* into an entirely different family,[2] but so defines it that it cannot possibly continue to include Carter's *Conulites*. So, as he apparently makes no other provision for the original *Conulites*, but seems to ignore it altogether, members of that type seem to be excluded from his system; or, at least, they find no clearly recognisable position in it.

The trouble seems to be, so far as the genus *Conulites* is concerned, that representatives of it do not appear to be found outside of India in the same way that representatives of the other two great genera (or families) are; so that while European geologists are kept constantly alive to the necessity for providing in their classifications for *Orbitolinae* and *Patellinae*, the distinct existence of *Conulites* has been lost sight of, ever since Carpenter minimised its right to separate recognition. Yet the genus is very well represented in India, by several species, one of which is found in great numbers over a large geographical area. It seems necessary, therefore, that students of Indian geology should take serious note of the existence of this genus; and that cannot be done better than by reviving, with slight modification, Carter's original description of it.

Description of Genus.

Test calcareous and finely tubulated. Form conical, with base varying from concave to convex. The upper surface shows a superficial skin, thickest in the middle and thinning to the sides, traversed

[1] *Palaeontology*, Vol. I, 1913, p. 27 and fig. 12.
[2] *Ibid*, p. 33.

by short pillars. Below this lies a single layer of large and deep cortical chambers, rhomboidal in plan, not subdivided by any system of subsidiary partitions, and arranged in a spiral row, with generally a number of intercalary rows appearing between the whorls of the original one. The umbilical area is filled with small secondary chambers, disposed in layers parallel to the base, and traversed by numerous vertical pillars analogous to those of the superficial skin.

Thus defined, it is seen that the genus is a very well marked one, and easily distinguished from the types, *Patellina* and *Orbitolina*, with which it has so often been confused, but neither of which is adapted to receive it.[1] The following representatives of this genus appear on the North-West Frontier of India :

Conulites kohaticus, n. sp.

Figs. 1 to 5 (*c*).

General Remarks.—This form has now been found by me in great numbers, from the Jowaki border, 6 miles east of Kohat, to Thal, 60 miles west; in many places (notably Bahadur Khel) between Kohat and Latambar, 50 miles south; near Saidgi, 15 miles west of Bunnu; and on the Harnai-Spintangi line in Baluchistan; in other words, over an area more than 60 miles broad by 300 deep. The actual distribution appears to be even more extensive. Thus Wynne, when describing the beds at Bahadur Khel,[2] says that the section there " contains the large thin *rotalinae* so characteristic of the " Subathu " nummulitic bands in the Potwar "; and it seems to me (since I kn w the Bahadur Khel section very well) that he can only be referring to this form. There is no other there that would answer to this description; and he could not have failed to notice this one, which he does not otherwise mention.

[1] In their paper, mentioned in the first note on p. 238, Schlumberger and Douvillé show that Carter's *Conulites*, as represented by *cooki*, cannot be affiliated with *aegyptiensis*. They point out that *cooki* exhibits affinities both with Assilines and Orbitoides, and suggest that the genus *Conulites* should be studied afresh. That is what I have tried to do here, showing how both the structure and the ontogeny of the genus indicate its true association with Nummulites and Orbitoides. The remarkable thing to my mind is that Schlumberger and Douvillé should have anticipated this finding on the very little material at their disposal.

[2] *Mem., Geol. Surv. Ind.*, Vol. XI, Pt. 2, page 139.

But in that case this form must also be found in Nummulitic rocks nearly 100 miles east of Kohat. Besides this, I have found numerous specimens of this identical species in the collections of the Geological Survey at Calcutta, which are registered as having been found in Lower Sind, at such places as the Dharan Pass, Maliri Landi, Ranikot, Trak Hill, Sumbuk Hill, the Habb River, etc.[1] Thus the form seems to have been collected almost wherever Eocene rocks have been found on the N. W. Frontier, over an area more than 150 miles broad by 600 deep.

Description of Species.—The form is that of a depressed cone, the upper surface being convex with central boss, while the lower surface is generally concave. Variations in shape are generally to be seen at the outer margin of the test, which is sometimes thin and inclined downwards, sometimes thick and recurved upwards, with many gradations in between.

Both surfaces are granulated. On the upper surface the granulations are large, globular, and close-packed in the region of the central boss, but diminish in size the further they are removed from it, elongating themselves radially, and assuming a spiral arrangement round the centre, following the course of the cortical chambers beneath. Finally, towards the outer margin of the test, the granulations disappear, and the underlying spiral rows of cortical chambers begin to show through the upper skin, which there becomes very thin.

This upper skin is often found to be weathered away, especially at the margin where thinnest, and the spiral arrangement of the underlying chambers is then seen very clearly. This spiral may either be right- or left-handed (*cf.*, Figs. 3 and 4). If any one row of chambers be traced backwards from the outer margin, it will be found that, on completing the whorl, some 8 or more other rows intervene between its two representatives. This shows that, towards the end, there are about 9 or 10 rows of chambers moving round in a combined group. Carter only figures one such intercalary row of chambers appearing in the cortical spire of *cooki* (*cf.* Fig. 9), and states that even this is exceptional, the spire in that species being "generally single throughout"; so *kohaticus* appears to be

[1] ... general ... debted to Mr. P. N. Mukerjee for helping me to find these specimens.

very distinct in this respect[1]. The cortical chambers of *kohaticus* are almost square in plan, the septa being only very slightly inclined forwards, and spaced at intervals only slightly exceeding their own length. There are about 100 chambers to the outer whorl in an adult specimen. The primordial chamber appears to be spherical, but I have not yet been able to find it clearly exposed, nor to detect dimorphism.

On the lower or concave side of the test the granulations are globular, uniform, and close-packed over the whole surface. The last chambers of the cortical series are sometimes seen (in the case of specimens with narrow and turned-down edges) at the outer margin of this surface.

An axial section of the test [Figs. 5 to 5 (*b*)] shows a single layer of deep, rather claw-shaped chambers, blunt on top and pointed below, underlying the convex upper surface. These chambers are covered by the skin, already described, thickest at the central boss and thinning to the sides. Passing vertically upwards through this skin are a number of small pillars [faintly discernible in Fig. 5 (*a*)], the ends of which appear to provide the granulations at the upper surface. Below the layer of large cortical chambers, and filling the hollow cone formed by the same, is a mass of much smaller chambers, apparently disposed in horizontal layers between the claw-like points of the cortical chambers. These secondary chambers are traversed by numerous vertical pillars analogous to those of the upper surface, but much more distinctly seen owing to their greater length, and much more crowded owing to their emergence from a concave surface. These pillars are somewhat conical in shape, being pointed on top and thickening as they descend; they do not always reach the lower surface, but are replaced by others if they fail to do so. The granulations on the lower surface of the test represent the rounded ends of these pillars as they emerge at that surface.

[1] A specimen with worn central boss [Figs. 4 and 4(*a*)]shows two intercalary rows of chambers appearing before the primary row has even completed two whorls; that is to say, within the first ⅛th part of the radius of the adult test. Owing to the rate at which intercalary rows appear, the "twist" of the primary row rapidly opens out; so that, although the row itself does not widen appreciably in this species (it does widen in others), there are only about 4 or 5 whorls altogether. Thus, in one specimen examined, the first whorl was apparently represented by the first lateral chamber in the radius, the second by the next 3, the third by the following 10, and the fourth and last by the outer 11. It seems from this that new intercalary rows were more freely developed in early than in later life.

A horizontal section of the test [Fig. 5 (*c*)] shows the large rectangular chambers of the cortical series in plan, at its outer margin, while many small dark circles in its central portion seem to represent the sections of the vertical columns above described. It will be noticed that, whether seen in vertical or cross section, the large cortical chambers appear to be simple, without any such system of secondary internal partitions as exists in the genus *Orbitolina.*[1]

Distinction, and Stratigraphic Horizon.– The above species thus possesses all the main characteristics of the original genus *Conulites*. These, as described or figured by Carter, are :– (*a*) Conical shape ; (*b*) Superficial granulated skin, thickest at the apex and thinning to the sides ; (*c*) A single layer of large and simple cortical chambers, deep in vertical section and rhomboidal in plan, arranged in a spiral which is apt to bifurcate, or display intercalary rows ; (*d*) A mass of small secondary chambers arranged in layers parallel to the base and filling the umbilical part of the test ; and (*e*) Numerous vertical pillars, pointed on top, which traverse the layers of secondary chambers, and form crowded granulations on the surface below.

It seems, therefore, that *kohaticus* is generically identifiable with *Conulites cooki* : but a specific identification cannot be so clearly established. Thus Carter represents *cooki* as possessing a relatively much higher test, a convex lower surface, relatively much larger cortical chambers, and few if any intercalary rows of such chambers. I was unable to check matters at Calcutta, since I could find no specimens, in the Geological Survey collections there, which were certified as identical with *Conulites cooki.*[2] Carter's original specimens of *cooki* were, according to Chapman, mounted on Slide No. 40 of the Carter Collection, and to be seen (in 1900) in the Geological Society's Museum.[3] The collections in that Museum have, however, since been taken over by the British Museum ; so I applied to the latter, for direct comparison of my specimens with Carter's

[1] I do not state the usual dimensions of this and other species here described, since such data can be obtained from the photographs at the end.

[2] Specimens in the collections at Calcutta are variously labelled "Conulites" or "Patellina cooki," etc., never *Conulites cooki.* As "Conulites" they were apparently regarded as distinct from *cooki* ; as "Patellinae" they could not help being attributed to *cooki*, however much or constantly they might differ in details, since the generic characters themselves were reduced to specific grade.

[3] According to Chapman (*Geol. Mag.*, as above, p. 12), the specimens of *cooki* on slide No. 40 were numbered 2 (from Kelat), 3 (from Sind), and 4 (from Arabia). This mention of a specimen from Arabia is interesting, as showing that the genus is not restricted to India ; but as this is the only allusion I have yet seen to an extra-Indian discovery of the type, I will do no more at present than simply draw attention to it.

Slide 40. In reply, Dr. W. D. Lang writes as follows: "I have made a thorough search for Carter's Slide 40 in the Geological Society's Collection, which is now here, and cannot find it. Moreover, *Conulites* [*Patellina*] *cooki* is not mentioned in J. F. Blake's 'List of the Types and Figured Specimens recognized by C. D. Sherborn in the Collection of the Geological Society of London, verified and arranged with additions,' 1902. I suppose, therefore, that the slide was missing from the Geological Society's collection at that date........ So I am afraid that the type is lost, and only the figure is left on which to found an opinion."[1] It is possible, of course, that the slide may some day be found, but it does not seem very probable in view of Dr. Lang's remarks. So all we have at present, in regard to *cooki*, are Carter's figures and written description of it; and since these all seem to represent a form specifically quite distinct from the type here described, we must either regard the latter as a new species, or else impugn, without evidence, Carter's description of *cooki*. Assuming, then, that Carter's details are as accurate as his more general observations, I regard my own species as distinct, and propose to name it *kohaticus*, both from the region in which I first collected it in large numbers, and from the zone, "Kohat Shale," which it peculiarly characterises.

That zone is the highest one hitherto identified as belonging to the Laki stage, and corresponds to the lower portion of Mr. Pinfold's "Upper Chharat."[2] It immediately underlies the "Nummulite Shale," overlies the Ghazij Shale (or "Lower Chharat") and is well represented in many places west of the Indus, where it is generally found to contain great numbers of *kohaticus*, undoubtedly *in situ*. The Kohat Shale was apparently a marine shallow water formation, since it contains *Corbula*, *Ostrea*, and limbs of crabs, etc.; and it is noticeable that all trace of *Conulites*, seems to disappear in the Nummulite Shale above, where the abundant molluscs of the Kohat Shale are replaced by *Pycnodonta* [*Gryphaea*] cf. *vesicularis* which (*i.e.*, *Pycnodonta*) indicates, according to H. Douvillé, deeper water than *Ostrea*.[3]

As I have elsewhere pointed out,[4] there is reason to believe that the base of the Indian Khirthar (represented locally by the Num-

[1] Letter of 3/12/1924.
[2] *Rec. Geol. Surv. Ind.*, Vol. XLIX, Pt. 3, pp. 137—160.
[3] *Pal. Ind.*, N. S., Vol. V, Mem. 3, pp. 12—13.
[4] "Notes on the Correlation of Pinfold's Chharat Series with the Eocene Stages of Sind and Europe" (*Trans. Mining and Geol. Institute of India*, Vol. XX, part 3).

mulite Shale) corresponds to the base of the Lutetian in Europe; so the Kohat Shale would represent an uppermost Ypresian horizon (the Laki, as a whole, representing the middle and upper Ypresian).

Conulites kohaticus var. *spintangiensis*, n. var.

Fig. 6.

Variations in size and form exist, even at Kohat, between representatives of *C. kohaticus*; and as one goes south one finds that a bigger and flatter form becomes the more normal type. This appearance of flatness is due to the thickening and turning upwards of the outer rim of the test. The change is apparent even at Bahadur Khel, in beds the exact counterpart of those at Kohat; and it is most noticeable of all at Spintangi, where very large forms (some up to 2 c.m. in diameter) are to be found.

As individuals of the southern type are found at Kohat, however, while individuals typical of Kohat are found even at Spintangi, with every grade in between at both places, I do not feel justified in creating a new species to define the more southern type,[1] but propose to class it as a variety, *spintangiensis*, of *kohaticus*.

Stratigraphic Horizon.- The Spintangi rocks are generally regarded as representing an Upper Khirthar horizon. If that is correct, then *Conulites* is undoubtedly found in the Upper Khirthar. Personally, however, after examining the Harnai-Spintangi area, I am very doubtful whether the accepted opinion can be right; I am inclined, for reasons which I cannot go into here, to regard the Spintangi rocks as probably just a special facies of the Upper Chharat (*i.e.*, uppermost Laki and basal Khirthar). In any case, *Conulites* there appears among much the same associates as in the Kohat Shale, and has not yet been found by me in a deep water formation.

Conulites kohaticus, var. *blanfordi*, n. var.

Although many specimens of *Conulites* are to be seen in the collections of the Geological Survey at Calcutta, nearly all of them appear to conform either to the true *kohaticus* type or to its *spintangiensis* variety. There are, however, a few exceptions to this,

[1] I call it the "southern" type, since it is the more southern of the ones I have myself collected. It is noticeable, though, that the specimens from Lower Sind, still further south, often approximate to the normal *kohaticus* type rather than to the *spintangiensis* variety.

among which two specimens (numbered G.373/11) seem to represent a type sufficiently distinct to be separately described. An internal

X3
Section of G. 373/11.

section of one of these specimens, kindly made for me by Mr. Tipper, does indeed show the closest resemblance to the species *kohaticus*. The relative sizes of the cortical and secondary chambers are the same, as also the number of cortical chambers to the radius. There are, however, certain marked external differences which, being found in both specimens, appear to justify one in regarding them as belonging to a distinct variety of the species. Thus the test is relatively very high (diam. of base, 10 mm.; height, 3½ to 4 mm.), with distinctly pointed apex, straight sides, sharp margin, and slightly concave base. A singular feature about these specimens is the apparent absence of granulations on their convex surfaces, which are covered with a smooth or slightly corrugated skin. This absence of granulations on the upper surface might, indeed, be attributed to weathering, for a similar absence is occasionally seen on specimens of the normal *kohaticus*; but since both these specimens show it, while neither appears to be otherwise very weathered, it seems more likely that a smooth upper skin is a feature of the type. In that case, the great height of the test, together with the paucity of granulations on the convex side, may indicate a somewhat abnormal degree of specialisation in this variety.[1] I propose that it should be named after the well-known geologist who collected these two specimens.

Locality and horizon.—The specimens were collected by Mr. W. T. Blanford, in 1882, from the Eocene rocks just west of Mangrotah (Lat. 30° 40′ North; Long. 70° 30′ East), where such forms are said to be "numerous." The exact horizon is not at present known.

Conulites vredenburgi, n. sp.

Figs. 7 to 7(*b*).

Although the vast majority of *Conulites* that one sees along the N.-W. Frontier are clearly identifiable either with *kohaticus* or with its variety *spintangiensis*, yet I have in one spot found *in situ* a

[1] The development to the concave side being even more marked than usual, and that to the convex side even more neglected.

type of *Conulites* which does seem to differ specifically from *kohaticus*. It is a relatively small, flat form, with cortical chambers so large in proportion to the test as a whole, as to constitute in my opinion a specific difference in type. An adult of this species shows only about 15 cortical chambers to the radius, in axial section, as against 25 to 30 in *kohaticus* and *spintangiensis*, so that these chambers are altogether larger in proportion to the test as a whole. No gradations seem to exist between this type and *kohaticus*. I give sections of one of the largest and least flattened specimens found of this species, so that the proportions of its chambers and the shape of its test may be compared with the *kohaticus* type at a point where they approach it most closely. The spire has about 8 intercalary whorls.

Locality.—The species appears in certain limestone bands in a pocket of Eocene rocks, at a spot (Lat. 30° 39½′ North; Long. 67° 54½′ East) near Chrome Mine No. 136 at Hindu Bagh, in Baluchistan.

Horizon.—The existence of this pocket was recorded by Mr. Vredenburg some years ago, and its horizon registered by him as "Ghazij Shale." It is a marine, or estuarine, shallow-water formation, gypsiferous, with remains of *Ostrea*, *Cerithium chapari*, *Mactra dubia*, *Corbula*, *Natica*, etc.[1] As a Ghazij Shale formation, it would represent the horizon just below the Kohat Shale. I propose to name the species after the late Mr. Vredenburg, who first noticed this little pocket of Eocene rocks among the surrounding serpentines.

Conulites tipperi, n. sp.

Fig. 8.

In certain hand specimens of rock matrix, numbered G.280/77 in the collections at Calcutta, I found a third species of *Conulites*, very distinct from both of the foregoing. While it exhibits all the characters of the genus, it is remarkable by reason of its extremely small size (3 to 4 mm. diameter), its globular form, and its relatively

[1] Although containing an Eocene fauna, these beds are singularly devoid of all Nummulites, Assilines and Alveolines. The only other foraminifer which I have found in them, besides *vredenburgi*, is a small Orbitoline [s. lat., probably a *Dictyoconus*; shown in Figs. 13 to 13(*b*) below], of which both the megaspheric and microspheric forms are found in abundance. Chapman noted a similar strange absence of Nummulites (but not of Alveolines) in the beds containing *aegyptiensis*. This suggests that the conditions which suited Orbitolines were inimical to Nummulites; and so the stunted appearance of *vredenburgi* may represent its adaptation to unfavourable circumstances.

enormous cortical chambers which never seem to exceed in number 6 or 7 at most, to the radius, in axial section. The base is generally almost as convex as the upper surface; and the granulations on it are noticeably largest in the middle, instead of being uniform as in the other two species. The spire appears to be single throughout, and increases rapidly in size as it nears the periphery; so that the outermost cortical chambers are about half as wide again, and two to three times as deep, as the innermost ones. This feature is seen to some extent in *C. vredenburgi*, but it is more noticeable in the species now described by reason of the still smaller number of whorls in the latter, which renders their increase more noticeably rapid. The vertical pillars are well seen, in axial section, traversing the secondary chambers of the lower surface; and analogous pillars are seen, more prominent in the centre than to the sides, rising from the cortical chambers to the upper surface. I propose to name the species after Mr. G. H. Tipper, Palæontologist of the Geological Survey, by whom my attention was first drawn to these rock specimens, and who has very kindly helped me in working on them.

Locality.—The specimens were collected at Petiani, 10 miles west of Kotri (or about 11 miles west of Hyderabad, Sind).

Horizon.—The area round Petiani was mapped by Mr. Vredenburg as Alveolina Limestone. The associated foraminifera in these hand specimens, being *N. ramondi* and *Assilina granulosa*, certainly prove the horizon to be a Laki one; but the apparent absence of Alveolines makes it seem very improbable that these forms could belong to the Alveolina Limestone. The rock itself is also a shaley limestone, quite unlike the normal Alveolina Limestone matrix. There is, on the other hand, no record of any Eocene rocks, *later* than the Alveolina Limestone being found in the vicinity; but the presence not far to the south, of a large exposure of Meting Shales, makes it seem possible that these specimens were collected from some lesser northern outcrops of the same, which were too minute to be registered on Mr. Vredenburg's small scale map. Thus the species would appear to belong either to the middle or (more probably) to the lower levels of the Laki.

Ontogeny, Structure, and Classification of Conulites.

It seems possible that, in the earliest stages of growth of *Conulites*, the form is similarly developed on both sides of the equator,

without the conical bias to one side which becomes so distinct shortly afterwards. This appears to be indicated (1) by the more or less horizontal arrangement of the first few cortical chambers, as seen in axial section; (2) by the central "boss" on the convex surface, implying a greater thickness of superficial skin produced in the earlier, than in the later, stages of development; (3) by the fact that the granulations of the upper surface are at first (*i.e.*, in the region of the central boss) very similar to those of the lower surface, but become progressively fainter in the later stages of growth, and (4) by the fact that the spire has just as often a left-handed twist as a right-handed one.

All these facts seem to suggest that there may be first at no bias to either side, but only some want of internal equilibrium which subsequently impels a development to one side or the other. If it were left to some accident of growth to determine to which side the cone should be developed, it would be easy to see why the spire should be sometimes left and sometimes right-handed, and also why *further* development of both skin and pillars on the rejected (or convex) side should be curtailed, once the bias was determined to the favoured (or concave) side. For the bias to one side, and the curtailment of development to the other, seem to be correlated.

It seems best, therefore, from the ontogeny of *Conulites* as well as from the main facts of its structure, to regard it as a very aberrant genus allied to some form like *Nummulites* or *Orbitoides* which exhibits a bi-polar arrangement of secondary chambers on either side of an equatorial layer of large ones. Thus the simple but large cortical chambers of *Conulites* may be compared with the comparatively large equatorial chambers of *Nummulites*; while the incrustation on the convex surface of *Conulites*, together with the umbilical chambers on the concave surface, both traversed by numerous conical pillars, might represent the lateral chambers traversed by conical pillars of many *Nummulites* and all *Orbitoides*. The calcareous and finely tubulated nature of the test in *Conulites* further agrees with this proposed association.[1]

It is true, of course, that no close affinity can be claimed. Thus the rhomboidal form of the cortical chambers in *Conulites*, and their spiral arrangement, forbid too close an association with *Orbitoides*; while the same rhomboidal form of the chambers, and the tendency

[1] The tubulation of the test is best seen in Fig. 7 (*b*) below.

to develop numerous intercalary rows of chambers in the spire, emphasise its distinction from *Nummulites*. No doubt *Conulites* should be placed in a position parallel to those great genera, rather than in succession to either. Still, it appears to find its most natural place in the same family with them; so I suggest that it should, at present, be classed as the typo-genus of a new sub-family CONULINIDAE of Zittel's family NUMMULITIDAE.

In conclusion I wish to say how indebted I am to Dr. Pascoe, Director of the Geological Survey of India, for many facilities freely given to study in the offices, and refer to the library and collections of the Geological Survey in Calcutta; to Dr. Baini Prashad, Officiating Director of the Zoological Survey of India, and Dr. C. S. Fox and Mr. Watkinson of the Geological Survey, who have most kindly taken for me all the photographs of micro-sections here produced; to Mr. Tipper and Mr. Lahiri of the Geological Survey, for much advice and practical help; also to many other officers of both Surveys, for incidental assistance of all kinds constantly given.

This paper was written in June 1925, before it was known that anyone else was working on the same genus. Mr. W. L. F. Nuttall of Cambridge has, however, since this paper went to press, published a description of a species from the middle Khirthar which he identifies with Carter's *cooki*; and another species from the upper Ranikot, which he names *conditi*. Neither of these species is identifiable with the forms described here. Mr. Nuttall points out that Carter's name for the genus, *Conulites*, is preoccupied, and he substitutes for it the name *Dictyoconoides*. It should therefore be understood that all references to *Conulites* in the text refer to the genus now known as *Dictyoconoides* (Nuttall).

For Mr. Nuttall's papers, *see*—

"Two Species of Eocene Foraminifera from India," *Annals and Magazine of Natural History*, Ser. 9, vol. XVI, pp. 378—388, October 1925.

"The Larger Foraminifera of the Upper Ranikot Series (Lower Eocene) of Sind, India", *Geological Magazine*, Vol. LXIII, pp. 112—121, March 1926.

For Prof. H. Douvillé's remarks on the same, *see*

"La Forme Conique chez les Foraminifères, et le genre *Dictyoconus* Nuttall", *Comte Rendu Sommaire des Séances de la Société Géologique de France*, 1er février 1926, p. 19.

	No.	G. S. I. Reg. No.	
Plate 16	1	397	*Conulites kohaticus.* External view of unweathered test; convex surface. (×6).
	2	399	The same specimen, concave surface. (×6).
	3	390	External view of the upper surface of a weathered test, showing rows of cortical chambers Note the right-handed twist of the spire. (×6).
	4	398	Another specimen, with central boss removed, showing primary whorls. Note the left-handed twist of the spire. (×6).
	4 (*a*)		Sketch of primary whorls in above, showing 2 intercalary rows of chambers.
Plate 17	5		Axial section of another specimen, showing cortical and umbilical chambers, with pillars traversing the latter. (×6).
	5 (*a*)	1262	As in 5, but further enlarged. Note structure of the central boss, formed by thickened supra-cortical skin with traversing pillars. (×12).
	5 (*b*)	1254	Another specimen much enlarged to show shape and simple character of cortical chambers. Note the conical pillars descending to form granulations on the lower surface. (×30)
	5 (*c*)	392	Horizontal section of a test. (×24).
	6		*Conulites kohaticus,* var. *spintangiensis.* Axial section. (×6).
	7		*Conulites vredenburgi,* Axial section. (×6).
	7 (*a*)	395	The same, further enlarged. (×13).

	No.	G.S.I. Reg. No	
	7 (*b*)	396	The same, again enlarged. Note the perforations of the cortical chamber walls. (×30).
Plate 18	8	516	*Conulites tipperi.* Axial section. (×20).
	9	3412	Carter's diagram of *Conulies cooki*, as reproduced by Carpenter under the generic name "*Patellina.*" For comparison with the specimens of *Conulites* figured above.
	10	3414	Carter's diagram of *Orbitolina lenticularis*, as reproduced by Carpenter under the generic name "*Patellina.*" For comparison with *Conulites.* Note the subdivisions of the cortical chambers, and absence of pillars traversing the secondary chambers.
Plate 19	11	3413	Williamson's diagrams of *Patellina corrugata.* This being the form for which the genus *Patellina* was created, our ideas as to that genus must be based upon its characters. So note the apparent absence of all supra-cortical development of skin or granules; the irregular subdivisions of the cortical chambers, and their arrangement in semi-lunar strips; the confused filling of the umbilical cavity, and the total absence of all pillars traversing the same.
Plate 20	12	1264	Carpenter's diagrams of recent Australian forms also classed by him as *Patellinae*, although they again seem to represent a distinct genus. Whatever the affinities of this type may be, the cyclical arrangement of its cortical chambers, their great depth, and the massed granules in the centre of the base of the test, form a combination of characters which forbid generic identification with any other type here discussed.
	13		An *Orbitoline* form (*Dictyoconus*; megalospheric generation) associated with *C. vredenburgi* near Hindu Bagh. (×6).

No.	G.S.I. Reg. No.	
13 (*a*)	394	The same, further enlarged, for comparison with the *Conulites* type. Note the subdivisions of the cortical chambers, absence of supra-cortical skin, etc., and absence of all pillars through the umbilical region. (×30).
13 (*b*)	1257	Cross section of the same species, for comparison with 5 (*c*). Note the subdivisions of the cortical chambers, and their cyclical instead of spiral disposition as shown by the appearance of only one whorl in this section. (×30).

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